

Ethnobiological knowledge, quantitative assessment, and socio-cultural valorization of *Juniperus turbinata* among local communities across Morocco

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Abstract. El Annaoui A, Ait Bella Y, Haddioui A, Ezzine A, Dani S, Abd-Dada H, Bouda S. 2026. Ethnobiological knowledge, quantitative assessment, and socio-cultural valorization of *Juniperus turbinata* among local communities across Morocco. *Asian J Ethnobiol* 9 (1): y090109. <https://doi.org/10.13057/asianjethnobiol/y090109>. Red juniper (*Juniperus turbinata*) is an endemic Mediterranean species with longstanding medicinal, veterinary, cultural, and economic uses in Morocco, yet no comprehensive, species-focused, nationwide ethnobiological assessment has been conducted. This study documents and analyzes traditional knowledge and practices related to the species across its Moroccan distribution. A total of 518 informants, including 60 herbalists, were surveyed between 2023 and 2024 through semi-structured interviews. Several ethnobotanical indices were applied, including the Relative Frequency of Citation (RFC), Fidelity Level (FL), Cultural Importance Index (CI), and Use Value (UV), supported by a comparative literature review. Results show that red juniper is widely known and used for medicinal purposes. The medicinal RFC is 0.895, the UV is 4.34, and the medicinal CI reaches 3.86, confirming its major role in traditional pharmacopoeias. Aerial parts are predominantly used. Therapeutic applications mainly target respiratory, digestive, dermatological, and metabolic disorders, mostly through infusions and decoctions. Knowledge and Use Popularity Index (KUPI) analysis reveals high knowledge and perceived importance but only moderate actual use, particularly among younger and more educated informants. Chi-square tests show that sex, occupation, and education significantly influence perceived medicinal importance, while therapeutic preferences are strongly associated with age, education level, occupation, geographical area, and duration of residence. The veterinary dimension represents 35.5% of citations, with veterinary RFC=0.355 and veterinary CI=0.772, mainly for ruminants. Economically, professionalization indicates a market largely driven by experienced herbalists. Despite its nationwide scope, the study relies on self-reported knowledge, which may introduce recall or reporting biases and should be taken into account. Overall, the findings highlight the biocultural significance of *J. turbinata* and support the integration of local knowledge into community-based management, conservation planning, and sustainable valorization strategies.

Keywords: Cultural importance index, ethnopharmacology, *Juniperus turbinata*, traditional knowledge, veterinary ethnomedicine

INTRODUCTION

Red juniper (*Juniperus phoenicea* L. complex), locally known as "arar," is an endemic species of the Mediterranean basin (Maire 1952). Recent morphological and genetic analyses indicate that this is a species complex comprising three entities: *Juniperus phoenicea* L. s.s., found on the Iberian Peninsula and in Southern France; *J. turbinata* Guss., characteristic of Mediterranean Coastal Zones and the mountains of Northwest Africa; and *J. canariensis* Guyot and Mathou, endemic to the Canary Islands (Adams 2014; Mazur et al. 2018). The distribution of the species complex extends from the Atlantic coasts of Portugal and Morocco to the eastern Mediterranean and the Middle East, including major Mediterranean islands (Farjon and Filer 2013; Pavon et al. 2020). In Morocco, *J. turbinata* occurs in three ecotypes (arborescent, shrubby, and creeping) and occupies a broad ecological range, from coastal dunes (Essaouira-Saïdia) to the Atlas Mountains at elevations between 1,000 and 2,150 m above sea level (asl), under semi-arid to arid climatic

conditions with annual rainfall ranging from 200 to 400 mm (Benabid 1985; Quezel and Gast 1998; Benabid 2000; Farjon and Filer 2013; El Annaoui et al. 2025).

Juniperus turbinata is a slow-growing evergreen conifer, typically occurring as a shrub (3-5 m) or a small tree reaching up to 8-10 m in height, with dense branching and a trunk diameter generally below 20 cm (Quezel and Gast 1998; Benabid 2000; El Annaoui et al. 2025). Beyond its ecological significance, *J. turbinata* holds substantial cultural, artisanal and economic importance. Its fragrant, durable wood is used in cabinetmaking, artisanal marquetry, and as firewood, while its fruits and resin are utilized in traditional medicine, cosmetics, and certain symbolic rituals (Boratyński et al. 2024). This knowledge, transmitted primarily through oral traditions, forms an essential component of Morocco's intangible biocultural heritage and reflects the long-standing interdependence between local communities and their natural environment (Lahsissene et al. 2009; Rhattas et al. 2016). In many rural areas, plant-based knowledge and practices constitute important cultural ecosystem services, and contribute to

socio-ecological resilience and support for local livelihoods (Rankou et al. 2015; Eddouks et al. 2017; El Moussaoui et al. 2020).

Morocco hosts a remarkable floristic diversity, including over 800 aromatic and medicinal species that remain central to primary health care, particularly in rural areas (Rankou et al. 2015; Eddouks et al. 2017; El Moussaoui et al. 2020). Despite advances in pharmacology and clinical research, the persistent reliance on medicinal plants reflects their cultural embeddedness and therapeutic relevance (Lahsissene et al. 2009; Eddouks et al. 2017). Within this context, a robust ethnobiological understanding of culturally important species such as *J. turbinata* is crucial for linking traditional practices to conservation and sustainable use.

Although *J. turbinata* is frequently mentioned in regional, multispecies ethnobotanical surveys, no nationwide, species-focused ethnobiological assessment has been conducted in Morocco. Most existing studies have focused on ecological, chemical, or pharmacological aspects within limited regions (Rif, High Atlas, Anti-Atlas), leaving socio-cultural, economic, and integrative ethnobiological dimensions insufficiently documented. This fragmentation limits comparative analyses and hinders the translation of local knowledge into national conservation and management strategies.

To address this gap, this study adopts a pan-Moroccan integrative framework to provide the first comprehensive ethnobiological assessment of *J. turbinata*. Specifically, this study aims to: (i) Document and analyze traditional knowledge and practices related to *J. turbinata* across its ecological and cultural gradients in Morocco; (ii) Identify the most commonly used plant parts and cross-domain

applications (medicinal, veterinary, economic, cultural) using quantitative ethnobotanical indices; (iii) Assess the diversity, frequency, and perceived importance of uses and explore the socio-demographic factors shaping knowledge transmission; and (iv) Propose evidence-based recommendations for sustainable valorization, participatory management, and integrated conservation of this heritage species. By combining quantitative ethnobotanical indices with socio-demographic analyses, it offers an integrated understanding of traditional knowledge, uses, and perceptions, and explicitly links local ecological knowledge to conservation relevance and sustainable valorization.

MATERIALS AND METHODS

Study area

The survey was conducted between 2023 and 2024 across 14 ecological stations representing the natural distribution range of *J. turbinata* in Morocco (Figure 1). These sites span five major bioclimatic sectors (coastal areas, Rif, Middle Atlas, High Atlas, and Anti-Atlas), covering elevations from 5 to 1,900 m above sea level and climates varying from arid to humid (Table 1). Together, these sites were selected to encompass the full ecological and bioclimatic gradient occupied by the species across Morocco. This study was designed to ensure broad ecological and cultural coverage of *J. turbinata* in Morocco, rather than to achieve statistical national representativeness of the human population.

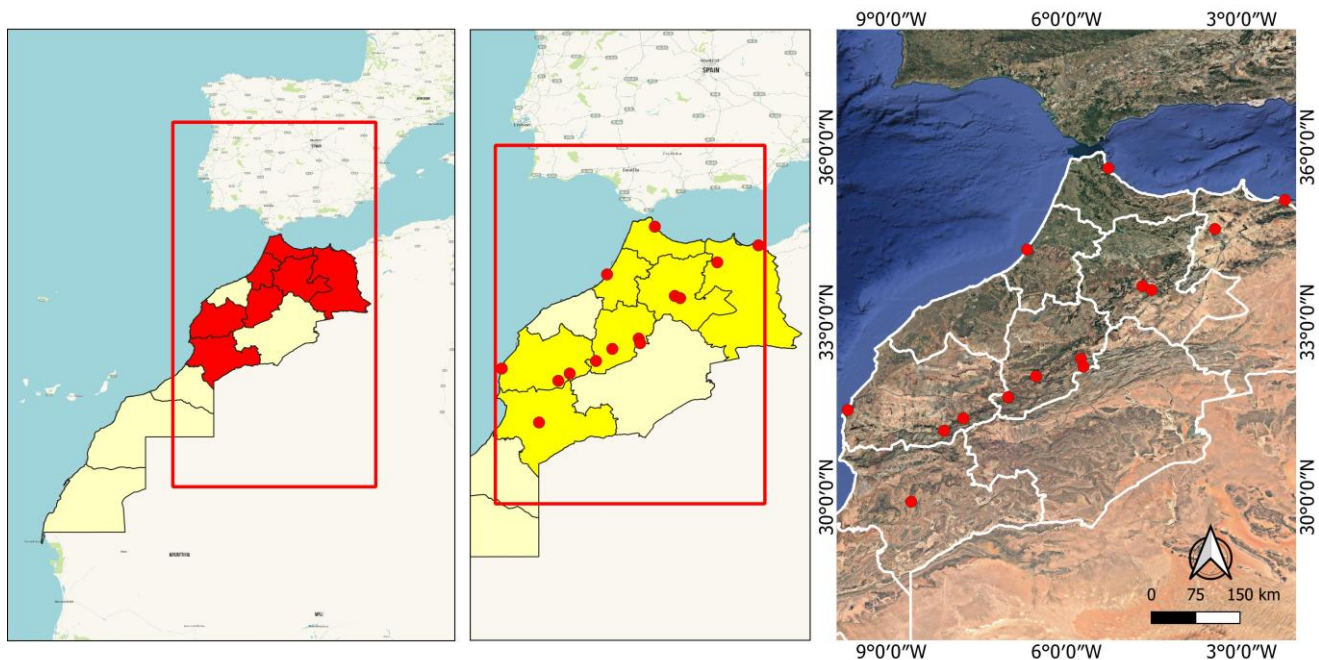


Figure 1. Map of Morocco showing the locations of the *Juniperus turbinata* Guss. populations included in the study (El Annaoui et al. 2025)

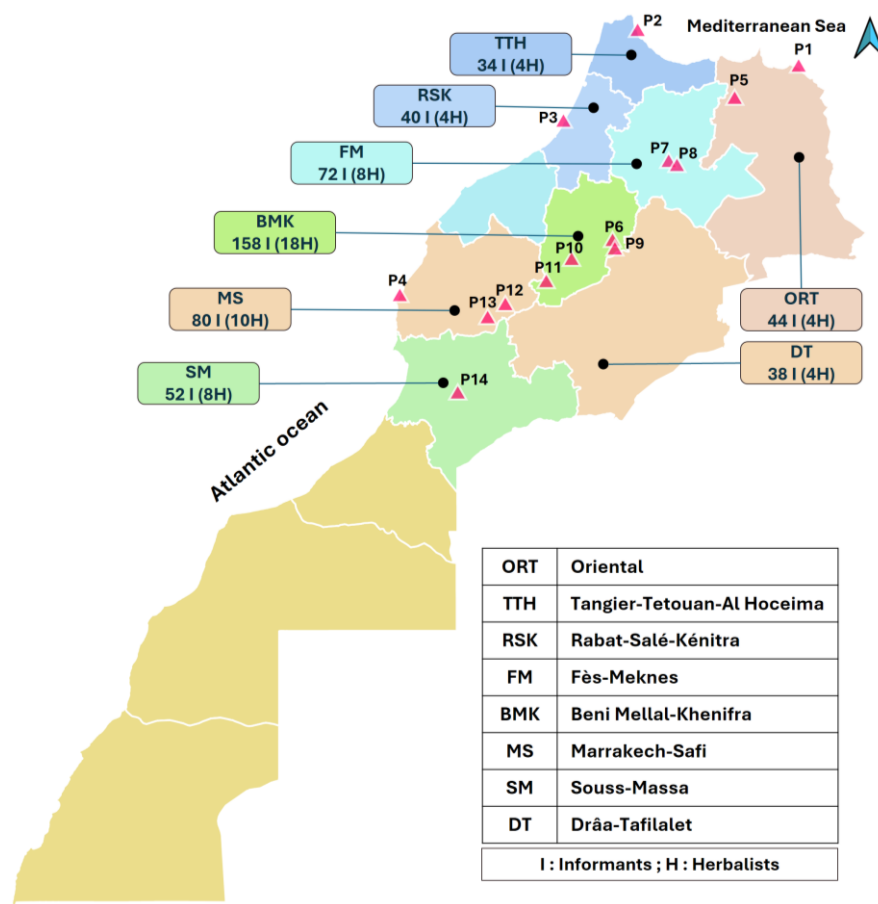


Figure 2. Distribution of informants and herbalists across Moroccan administrative regions in the *Juniperus turbinata* survey

Table 1. Geographic and meteorological conditions of the *Juniperus turbinata* natural populations included in the study

Population	Code	Geographical zone	Bioclimate Zone	Altitude (m asl)
Saïdia	SAD	Littoral	Semi-arid	5±1 m
Martil	MAR	Littoral	Semi-arid	10±2 m
Mehdia	MEH	Littoral	Semi-arid	10±1 m
Essaouira	ESS	Littoral	Arid	20±3 m
Sakka	SAK	Rif	Humid	915±3 m
Boutfarda	BTD	Middle Atlas	Semi-arid	1473±5 m
Tazouta	TZO	Middle Atlas	Humid	1542±3 m
Skoura	SKR	Middle Atlas	Semi-arid	898±3 m
M'Daz				
Imilchil	IML	High Atlas	Semi-arid	1914±3 m
Azilal	AZI	High Atlas	Semi-arid	1403±3 m
Demnate	DEM	High Atlas	Semi-arid	1080±3 m
Ourika	ORK	High Atlas	Arid	921±10 m
Amesguen	ASG	High Atlas	Semi-arid	927±4 m
Ait Abdallah	AAL	Anti-Atlas	Arid	1718±3 m

Selection of respondents

Surveys involved informants living in administrative regions where the species is present or traditionally valued, notably Beni Mellal-Khenifra, Marrakech-Safi, Fez-

Meknes, Souss-Massa, Oriental, Rabat-Salé-Kénitra, Drâa-Tafilalet, and Tangier-Tetouan-Al Hoceima (Figure 2).

Participants were selected using a random-route sampling method, walking through neighborhoods and rural areas and approaching households or shops at regular intervals. This method was applied in both urban and rural settings and helped reduce spatial clustering while ensuring socio-demographic diversity. At each stop, an adult volunteer (18 years or older), including formally adult high-school students, was invited to participate.

Eligibility criteria required permanent residence in the locality for at least five years. Importantly, both individuals familiar with *J. turbinata* and those who did not recognize the species were included. Including non-knowledge holders allowed a more accurate estimation of knowledge distribution and reduced user-based selection bias in the calculation of ethnobotanical indices. When several eligible individuals were present within a household, the respondent was selected through a simple random draw to avoid selection bias. This approach enabled the inclusion of all education levels, from no formal schooling to university, and a wide range of socio-professional categories, including adult students, farmers, artisans, merchants, civil servants, researchers, and teachers. While this procedure ensured a broad socio-demographic representation, it did not aim for strict national representativeness, which was not feasible due to logistical

constraints. In addition, herbalists operating within or outside the natural distribution range of the species were interviewed to document trade networks and the transmission of phytotherapeutic practices related to *J. turbinata*.

Questionnaire design and data collection

A structured questionnaire was developed based on previous ethnobotanical research (Rhattas et al. 2016; Hachi et al. 2022; Abd-Dada et al. 2025) and adapted to the socio-cultural context of the study area. Prior to large-scale data collection, the questionnaire was pilot-tested on a limited number of respondents to ensure clarity, cultural relevance, and consistency of responses. The tool was divided into seven sections, covering: (i) general and socio-demographic information; (ii) knowledge of *J. turbinata*; (iii) plant parts used and collection practices; (iv) preparation methods and medicinal uses; (v) veterinary applications; (vi) commercial aspects for herbalists and traders; and (vii) cultural importance and conservation attitudes.

The questionnaire combined closed, semi-closed, and open-ended questions, allowing both quantitative and qualitative data to be collected. Respondents included people who were familiar with the species as well as those who did not recognize it, which was essential for estimating knowledge frequency and calculating indices such as RFC and KUPI.

For medicinal and veterinary uses, ailments were categorized according to standardized ethnobotanical groupings (dermatological, digestive, respiratory, metabolic, neurological, etc.). To ensure data comparability, responses referring to similar symptoms or practices were harmonized into unified categories prior to analysis. Open-ended responses were coded and transformed into quantitative variables used to compute ethnobotanical indices, including RFC, UV, FL, CI, VPP, PI, and KUPI. Coding was performed using a predefined coding scheme to ensure consistency across interviews.

Interviews were conducted individually in the respondent's preferred language (Darija, Tamazight, Arabic, or French) and generally lasted between 20 and 40 minutes. Two main groups were surveyed: (i) herbalists ("Achabes"), to document commercial aspects and specialized phytotherapeutic knowledge; and (ii) farmers and other community members, to document local practices and perceptions.

Botanical identification

The identification of *J. turbinata* was performed using the main regional floras and monographs, including Flore pratique du Maroc (Fennane and Ibn Tattou 1998-2012), Flore et écosystèmes du Maroc (Benabid 2000), and conifer descriptions of Farjon (Farjon and Filer 2013). Diagnostic morphological characters (leaf arrangement, galbule morphology, seed number, growth habit) were compared with these taxonomic references. Particular attention was given to key diagnostic traits, notably the turbinate to ovoid shape of the galbules and the presence of a high number of seeds per cone. These characters were

carefully examined to minimize the risk of confusion with *J. phoenicea* s.l. Field identification was further supported through collaboration with forestry services (Water and Forest Administration), which provided official information on the natural occurrence of the species across surveyed sites. In addition, a previous morphological study conducted by our team (El Annaoui et al. 2025) confirmed that all collected specimens match the diagnostic traits of *J. turbinata* as described in international taxonomic literature.

Representative samples (twigs and cones) from the 14 ecological stations were collected and are preserved in the laboratory collection of the Faculty of Sciences and Techniques, Sultan Moulay Slimane University, Beni Mellal, Morocco, for reference, with full labeling of locality, date, and collector information.

Ethnobotanical indices

Relative Frequency of Citation (RFC)

The relative frequency of citation (RFC) was calculated following Tardío and Pardo-de-Santayana (2008) to assess the proportion of informants citing the species. To distinguish knowledge domains, RFC values were computed separately for medicinal and veterinary uses. The Relative Frequency of Citation (RFC) expresses the proportion of informants who cite the species for a specific use domain (Tardío and Pardo-de-Santayana 2008):

$$RFC = \frac{N}{N_t}$$

Where:

N_t : Total number of informants interviewed

N : Number of informants citing the plant for a specific domain (medicinal or veterinary).

In this study, two domain-specific RFC values were computed:

$$\text{Medicinal RFC} = N_{med} / N_t$$

$$\text{Veterinary RFC} = N_{vet} / N_t$$

Use Value (UV)

The Use Value (UV) was calculated following Phillips and Gentry (1993) to quantify the relative importance of the species based on the number of uses reported by each informant. The Use Value (UV) estimates the relative cultural and practical importance of a species in a community (Phillips and Gentry 1993):

$$UV = \frac{\sum U_i}{N}$$

Where:

U_i : Number of uses cited by informant i

N : Total number of informants interviewed

Value of the Plant Part (VPP)

The Value of Plant Parts (VPP) was calculated following Gomez-Beloz (2002) to identify which organs (leaves, fruits, twigs, etc.) were most frequently used. The Value of Plant Parts (VPP) expresses the relative frequency at which each plant organ is used (Gomez-Beloz 2002):

$$VPP = \frac{RU_{plant\ part}}{\sum RU}$$

Where:

$RU_{plant\ part}$: Total number of reported uses for a specific part of the plant

ΣRU : Total sum of reported uses for all parts of the plant.

Fidelity Level (FL)

The Fidelity Level (FL) was computed according to Friedman et al. (1986) to evaluate the consistency with which informants cited the species for specific therapeutic categories. The Fidelity Level (FL), proposed by Friedman et al. (1986), assesses informants' consistency in using a plant to treat a specific disease category. It is calculated as:

$$FL (\%) = \frac{N_p}{N} \times 100$$

Where:

N_p : Number of informants who cited the species for a given disease category

N : Total number of informants who reported any use of the species

Cultural Importance Index (CI)

The Cultural Importance Index (CI) was calculated following Tardío and Pardo-de-Santayana (2008) to assess the overall cultural relevance of *J. turbinata* across different usage domains. Two domain-specific indices were computed: the medicinal CI and the veterinary CI, allowing cross-domain comparison of cultural importance. The Cultural Importance Index (CI) evaluates the overall cultural relevance of a species within a community (Tardío and Pardo-de-Santayana 2008). It is calculated as:

$$CI = \sum_{u=1}^{N_c} \frac{N_u}{N}$$

Where:

N_u : Number of informants citing the species for use-category u

N : Total number of informants interviewed

N_c : Total number of identified use-categories

To better capture domain-specific cultural patterns, two separate indices were computed:

Medicinal CI: calculated using only medicinal use categories

Veterinary CI: calculated using only veterinary use categories

Knowledge and Use Popularity Index (KUPI)

The Knowledge and Use Popularity Index (KUPI) was calculated using the method described by Pérez-Nicolás et al. (2018). This index combines three components: the proportion of informants who know the species, those who use it, and those who consider it important. The total KUPI value ranges from 0 to 3. To estimate the overall level of knowledge, use, and perceived importance of *J. turbinata*, the Knowledge and Use Popularity Index (KUPI) was calculated following Pérez-Nicolás et al. (2018). It integrates three components:

$$KUPI = M + U + I$$

Where:

M : Proportion of informants who know the species

U : Proportion of informants who use the species

I : Proportion of informants who consider it important

Each component ranges from 0 to 1, giving a total KUPI range of 0 to 3.

Professionalization Index (PI)

The Professionalization Index (PI) was calculated to assess the level of experience and professional stability of sellers involved in the commercialization of *J. turbinata*. It is based on the weighting of seniority classes, reflecting the maturity of the local industry and the degree of socio-economic integration of red juniper sales. The approach is based on the "Sustainable Livelihoods" conceptual framework (Walter 2001; Belcher et al. 2005), which identifies experience, stability, and activity diversification as key components. The Professionalization Index (PI) assesses the level of experience and professional stability of sellers involved in the marketing of red juniper. It is calculated as:

$$PI = \frac{\sum (p_i \times n_i)}{N_{\text{sellers}}}$$

Where:

p_i : Weighting assigned to each seniority class (1 to 4, from least to most experienced)

n_i : Number of sellers in class i

N_{sellers} : Total number of sellers surveyed

The approach is based on the "Sustainable Livelihoods" conceptual framework (Walter 2001; Belcher et al. 2005), which identifies experience, stability, and activity diversification as key components.

Statistical analysis and software used

Data from the survey forms were manually entered and integrated into a database for analysis. Ethnobotanical and economic indices (RFC, UV, FL, CI, KUPI, VPP, IP) were calculated based on the collected variables. Descriptive statistical analysis and chi-square tests were performed to evaluate associations between the different variables. All statistical processing was performed using IBM SPSS software version 25.0.0, supplemented by Microsoft Excel (Microsoft 365) for data management and organization.

In this study, all chi-square tests were two-sided, and a significance threshold of $p < 0.05$ ($\alpha = 0.05$) was used. The assumptions of the chi-square test (independence of observations and adequate expected cell frequencies) were verified and met prior to analysis. Because each comparison involved independent categorical variables, no correction for multiple testing was required. No missing values were present in the dataset, as all responses were verified during field collection and data entry.

Ethical considerations

This study complied with Moroccan national guidelines for research involving human participants. Under local regulations, no formal ethical approval was required for non-clinical, interview-based ethnobiological surveys. Verbal informed consent and oral community consent were obtained prior to field investigations, and anonymity and confidentiality were fully respected. All necessary authorizations were obtained to carry out the fieldwork.

RESULTS AND DISCUSSION

Socio-demographic characteristics of the respondents and their therapeutic choices

The survey involved 518 informants across the Moroccan range of red juniper, with the socio-demographic profiles are presented in Table 2. The majority of respondents lived in urban areas. A large proportion had resided in their region for more than ten years. Farmers constituted the dominant group, followed by teachers, university students, and herbalists. The age groups 20-40 and 40-60 were the most represented, with a slight male predominance. Education levels were heterogeneous, combining a substantial proportion of university graduates with a notable presence of respondents with no formal schooling.

Chi-square test results showed that gender, age, occupation, and education level significantly influenced therapeutic choices between traditional, modern, and combined medicine ($p < 0.001$). Place of residence also had a significant effect ($p = 0.006$), as did the length of residence in the region ($p < 0.001$). Bivariate analysis indicated that traditional therapy was mainly preferred by women over 40 years old, with lower education levels, and living in rural areas or villages. Conversely, more educated individuals in urban settings tended to use modern or combined therapy.

These findings highlight the strong influence of socio-demographic factors on therapeutic choices. The preference for traditional medicine among older women, particularly in rural settings, reflects their central role in family healthcare and in the intergenerational transmission of ethnomedicinal knowledge. In contrast, the tendency of younger and more educated respondents, especially in urban contexts, to favor modern or combined therapies may be associated with greater access to biomedical services, formal education, and standardized medical information.

Economic considerations, perceived effectiveness, and cultural familiarity continue to reinforce trust in traditional medicine, as reported in previous ethnobotanical studies conducted in Morocco and across the Maghreb (Allali et al. 2008; Boudjelal et al. 2013; El Hachlafi et al. 2020; Belhaj et al. 2021; Jaouad et al. 2025). However, the observed generational shift toward modern or combined therapies may weaken the intergenerational transmission of phytotherapeutic knowledge. Conversely, the strong adherence of older rural groups to traditional practices illustrates the resilience of culturally embedded healing systems. Overall, these patterns suggest that therapeutic choices are shaped by a dynamic interaction between cultural heritage, gendered knowledge transmission, education, and the urban-rural gradient, with direct implications for the continuity of traditional medicinal knowledge.

Table 2. Association between socio-demographic characteristics of informants and their therapeutic choices (Chi-square Test)

	Distribution	Number of informants	Percentage	Choice between the two therapies				χ^2	p-value
				TT	TM	TT+TM	NP		
Sex	Female	234	45.2%	60	36	128	10	88.669	0.000
	Male	284	54.8%	186	10	76	12		
Age	< 20	50	9.65%	4	18	24	4	102.143	0.000
	20-40	254	49.03%	100	20	122	12		
	40-60	192	37.07%	128	6	52	6		
	> 60	22	4.25%	14	2	6	0		
Occupation	Farmer	200	38.61%	148	4	42	6	287.09	0.000
	Teacher	96	18.53%	12	14	70	0		
	Civil servant	14	2.70%	8	0	6	0		
	Herbalist	60	11.58%	60	0	0	0		
	University student	68	13.13%	2	14	46	6		
	Housewife	46	8.88%	10	6	24	6		
	Merchant	16	3.09%	6	2	6	2		
	School student	18	3.47%	0	6	10	2		
	None	102	19.69%	94	2	4	2		
Education level	Primary	70	13.51%	58	4	8	0	228.183	0.000
	Secondary	90	17.37%	48	8	24	10		
	University	256	49.42%	246	46	204	22		
	None	102	19.69%	94	2	4	2		
Location of residence	Hamlet (Douar)	52	10.04%	16	2	34	0	17.949	0.006
	Village	98	18.92%	48	8	38	4		
	Town	368	71.04%	182	36	132	18		
	Nomad	0	0.00%	0	0	0	0		
Length of residence	< 1	8	1.54%	0	2	6	0	64.249	0.000
	1-5	10	1.93%	0	2	8	0		
	5-10	48	8.88%	12	16	18	2		
	> 10	452	87.64%	234	26	172	20		

Note: TT: Traditional therapy, TM: Modern therapy, TT+TM: Combined traditional therapy and modern therapy, NP: No preference

Level of knowledge, use, and perceived importance of red juniper

The KUPI yielded a value of 2.30/3 (76.5%) (Table 3), indicating a high level of knowledge, use, and perceived importance of *J. turbinata* among local communities. Most respondents were familiar with the species and considered it important, yet only about half reported using it regularly. This gap between recognition and actual use indicates that knowledge of the species remains widely shared, while its use is more selective and context-dependent.

Knowledge was based mainly on direct personal experience and intergenerational transmission, indicating that the species still circulates within family-based knowledge networks (Figure 3.A). Ecologically, most respondents perceived the stands as degraded, mostly due to grazing and wood harvesting (Figures 3.B and 3C), which may contribute to more restrained or selective use of the species at the local scale.

The most frequently cited uses, i.e. heating, crafts, traditional medicine, and animal feed (Figure 3.D), illustrate the multi-functionality of *J. turbinata*, confirming its socio-economic versatility. The KUPI highlights a strong level of cultural recognition of the species, even though its daily use remains more selective. The results show a simultaneous association of a high RFC and a high KUPI, suggesting that *J. turbinata* is not only widely recognized but also culturally valued, even though its daily

use remains more selective. This profile is consistent with that of other major medicinal species in Morocco, such as *Euphorbia resinifera* (Abd-Dada et al. 2025).

To our knowledge, this study is the first to quantify the socio-cultural importance of *J. turbinata* using integrated ethnobotanical indices (KUPI, RFC, FL, CI). Previous studies focused mainly on taxonomic, ecological, or pharmacological aspects, whereas our results highlight the cultural embeddedness and livelihood relevance of the species within contemporary communities. This contribution should nevertheless be interpreted in continuity with previous Moroccan ethnobotanical studies based on index approaches, while providing a species-focused and nationwide perspective.

Table 3. Knowledge, Use and Perception Index (KUPI)

Element evaluated	Number of citations	Proportion (p=n/N)
Knowledge of the species (K)	464	0.895
Use of the species (U)	270	0.521
Perceived importance (I)	456	0.880
Overall index (KUPI)	-	2.296
KUPI (%)	-	76.5 %

Note: Total number (N) of informants is 518

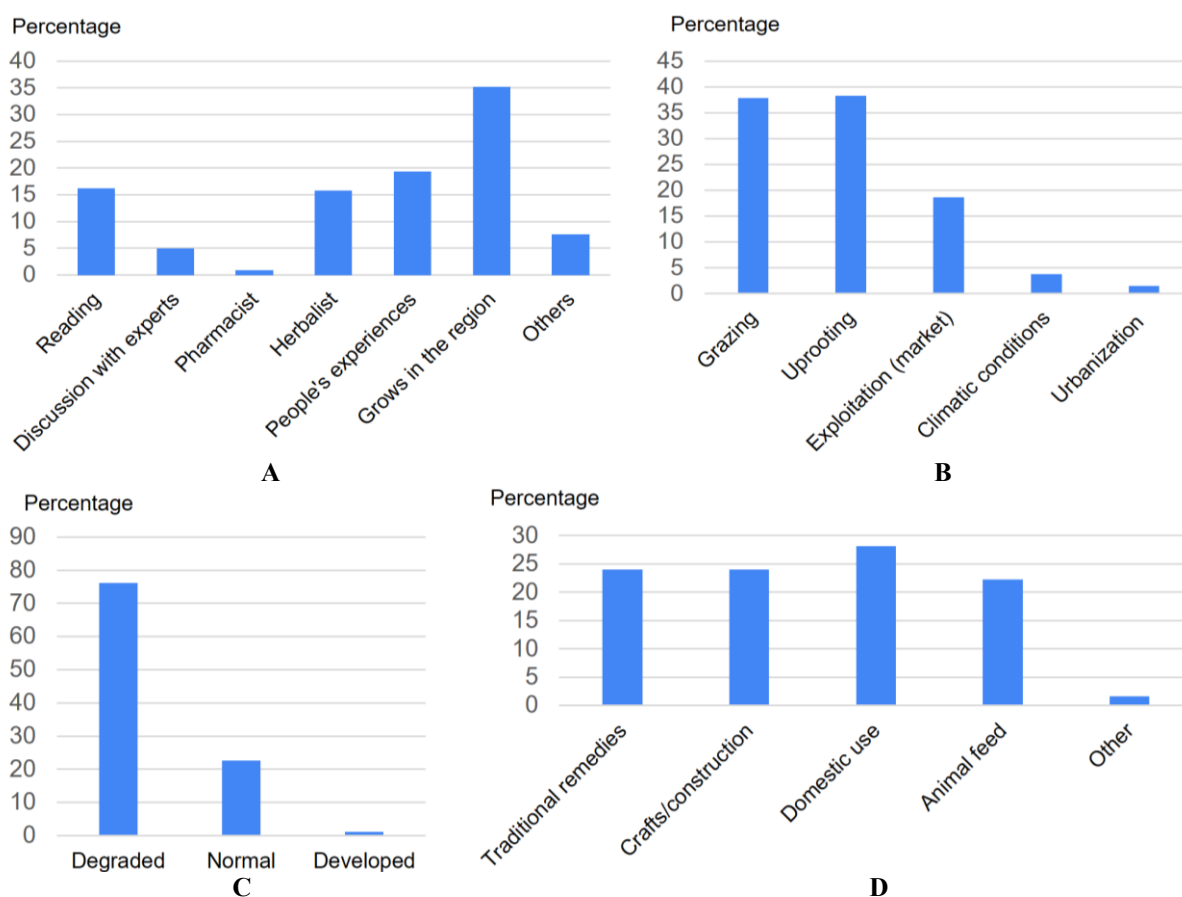


Figure 3. Results relating to the level of knowledge, use, and perceived importance of red juniper. A. Source of information, B. Causes of degradation, C. Condition of red juniper, D. Domains of red juniper exploitation

Uses of red juniper in traditional medicine

Level of Fidelity (FL) of the therapeutic uses

The Use Value (UV = 4.34) calculated for *J. turbinata* reflects its significant ethnopharmacological importance, with each informant attributing more than four therapeutic uses to the species. This diversity illustrates the medicinal versatility and central place of red juniper in traditional pharmacopeia, consistent with the confidence placed in local phytotherapy. Compared with other studies in Morocco and North Africa, this UV is exceptionally high, for comparison *J. phoenicea s.l.* reported UV values of only 0.0226 (Alami et al. 2021), 0.51 (Boudjelal et al. 2013), or 0.038 (Belhaj et al. 2021). This difference may partly reflect methodological differences and the species-focused design of the present survey, which captured the full range of uses attributed to *J. turbinata*.

Cross-analysis of Citation Frequency (CF) and Fidelity Level (FL) (Table 4) reveals the medicinal versatility of red juniper, with a clear predominance of digestive conditions, followed by dermatological and respiratory conditions. These results align with observations reported in the Mediterranean region (Boulos 1983; Bellakhdar et al. 1991; Lahsissene et al. 2009). The medicinal Cultural Importance Index (medicinal CI = 3.86) confirms this high cultural importance, reflecting the presence of red juniper in most of the therapeutic categories inventoried.

Dermatological uses are major, particularly for treating wounds, eczema, and injuries, often as poultices or local applications. These practices, also reported in northern Morocco (Smaili et al. 2023) and Algeria (Benlarbi et al. 2023), suggest a shared regional ethnomedicinal pattern for topical applications of the species. Digestive conditions are mainly treated with leaf decoctions. This aligns with observations by Boudjelal et al. (2013) and Alaoui et al. (2018), who report its use against gastrointestinal disorders.

Respiratory conditions, such as coughs, bronchitis, and asthma, represent the third main indication. Their use in infusions or fumigations is reported by Lahsissene et al.

(2009), El Hassani et al. (2013) and Briguiche et al. (2015). Diabetes is one of the most frequently mentioned metabolic uses (CF = 47.49%; FL = 53.02%), consistent with El Rhaffari and Zaid (2002), Allali et al. (2008) and Belhaj et al. (2021), who demonstrated a tangible hypoglycemic effect of leaf preparations. Other uses, such as for osteoarticular (Belhaj et al. 2020), neurological (Mouhajib 2002), or urogenital conditions (Bellakhdar et al. 1991), are less common but confirm the therapeutic diversity. Finally, cosmetic and aromatic uses (El Alami et al. 2016) highlight the economic potential of red juniper in the cosmetics and agri-food sectors (Samara et al. 2023).

These ethnomedicinal uses find pharmacological support in experimental studies reporting anti-inflammatory, antibacterial, and antifungal activities of *J. turbinata* extracts, which provide a general biochemical rationale for the traditional applications reported (Zouari et al. 2018; Aouadi et al. 2021; Samara et al. 2023; Asbabou et al. 2024; Chelouati et al. 2025). Overall, the convergence between traditional uses and reported pharmacological activities highlight the empirical robustness of *J. turbinata* and identifies priority domains where high FL values suggest the need for deeper phytochemical and clinical investigation.

Preparation of remedies which use red juniper

According to Table 5, red juniper is used either alone or in mixtures, with infusions, decoctions, and poultices representing the main preparation methods, confirming trends reported by Hachi et al. (2016) and El Hachlafi et al. (2020). The predominance of decoctions may reflect their cultural familiarity, ease of preparation, and suitability for treating commonly reported internal conditions, particularly digestive and respiratory disorders, whereas infusions are more often associated with milder or preventive uses.

Table 4. Citation Frequency (CF), Fidelity Level (FL), and Medicinal Cultural Importance Index (CI) of *Juniperus turbinata* according to the categories of treated ailments

Uses	Number of citations	CF %	FL %	Partial CI
Dermatological conditions	360	69.50	77.59	0.695
Digestive conditions	424	81.85	91.38	0.819
Respiratory conditions	272	52.51	58.62	0.525
Conditions of the accessory glands of the digestive tract	76	14.67	16.38	0.147
Cardiovascular conditions	124	23.94	26.72	0.239
Genitourinary conditions	166	32.05	35.78	0.320
Neurological conditions	80	15.44	17.24	0.154
Osteoarticular conditions	164	31.66	35.34	0.317
Metabolic conditions and diabetes	246	47.49	53.02	0.475
Cosmetics	80	15.44	17.24	0.154
Diuretic; antiseptic; anti-inflammatory	8	1.54	1.72	0.015
	--	--	--	Total CI=3.861

Note: Total number of informants is 518. Total number of informants who reported at least one use is 464. The partial Cultural Importance Index (CI) was calculated using the Frequency of Citations (FC) for each category; the total medicinal CI corresponds to the sum of these proportions (Total medicinal CI = 3.86)

Administration is often combined (oral and topical), indicating strategies aimed at maximizing perceived efficacy. This combined administration reflects the use of oral preparations for internal conditions and topical applications for external (mainly dermatological) conditions, as reported by respondents. Although outcomes are largely positive, they remain self-reported and may be subject to recall or desirability bias, highlighting the need for pharmacological confirmation. The very low reported toxicity is consistent with its reputation as a safe traditional remedy (Belhaj et al. 2021). Overall, these preparation and administration choices illustrate a preference for accessible and culturally familiar practices, closely linked to perceived effectiveness rather than standardized dosage.

Exploited parts and collection of red juniper

Aerial parts, mainly leaves (VPP = 37.4%), followed by twigs and fruits, constitute the bulk of medicinal uses (Table 6). This reflects preferential valorization of green tissues, rich in aromatic compounds and available year-round, whereas roots and bark are used only marginally.

Harvesting occurs throughout the year (45.6%), with a peak in summer (35.8%) (Figure 4.B). Most informants prefer cool early-morning hours to preserve active

compounds. Use of fresh plant material predominates (61.7%) (Figure 4.A), while drying (34.3%), almost exclusively in open air, allows for longer storage.

The harvesting of aerial parts in large quantities and underground organs in smaller amounts can remain sustainable when practiced moderately. However, repeated collection, particularly of leaves and twigs, may increase pressure on already degraded stands. This underscores the need for regular ecological monitoring to ensure the long-term sustainability of the species.

Table 6. Percentage distribution of plant parts used (VPP Index)

Part	Number of citations	VPP	VPP (%)
Leaves	482	0.374	37.4
Twigs	306	0.237	23.7
Fruits	290	0.225	22.5
Roots	14	0.011	1.1
Bark	166	0.129	12.9
Whole plant	32	0.025	2.5
Total	1290	--	--

Table 5. Characteristics of use, preparation, and effectiveness of remedies based on red juniper

Characteristics	Number of citations	Percentage	Characteristics	Number of citations	Percentage
Forms of use of red juniper			Preparation methods of red juniper remedies		
Single plant	364	45.5	Infusion	336	27.86
Association with other plants	182	22.75	Decoction	254	21.06
Association with honey	240	30	Poultice	254	21.06
Other	14	1.75	Raw	74	6.14
Usage forms of red juniper-based remedies			Cooked	46	3.81
Herbal tea	280	25.97	Maceration	212	17.58
Powder	206	19.11	Fumigation	30	2.49
Essential oils	202	18.74	Administration routes of red juniper remedies		
Fixed oils	114	10.58	Oral route	110	22.18
Extract (tincture, solution)	276	25.6	Topical route	38	7.66
Outcomes observed after using red juniper-based remedies			Both	348	Both routes
Recovery	292	58.87	Presence of toxicity related to the use of the remedy		
Improvement	198	39.92	Yes	36	7.26
Ineffective	6	1.21	No	460	92.74

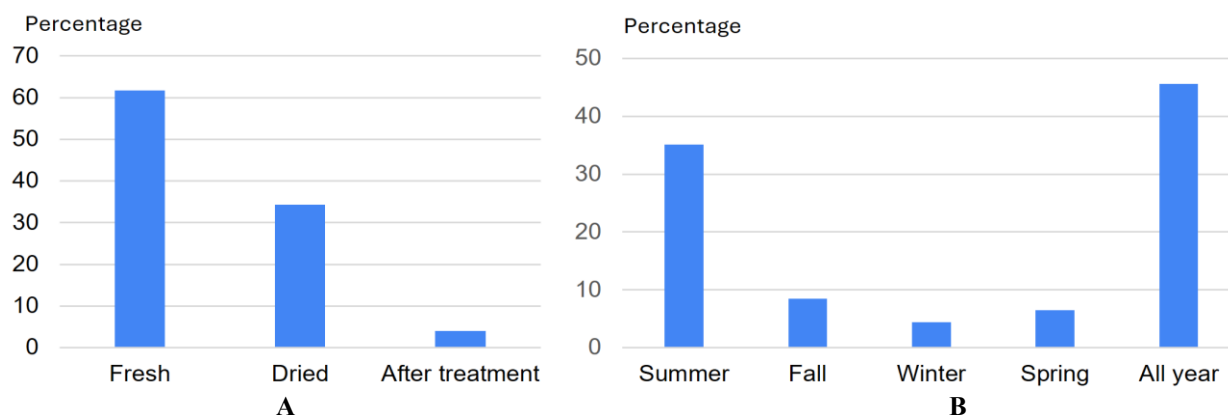


Figure 4. A. The form in which red juniper is collected or used; B. The annual collection period for red juniper

Uses of red juniper in veterinary medicine

Results in Table 7 show a high proportion of informants use red juniper to treat domestic animals (FC = 184; Veterinary RFC = 0.355), particularly sheep, goats, and cattle. These ruminants constitute the predominant livestock in the study areas, which explains their higher representation in ethnoveterinary practices. Their greater exposure to digestive, parasitic, and skin disorders are likely to reinforce the reliance on *J. turbinata* as an accessible and trusted remedy. These veterinary uses are more frequently reported in regions characterized by extensive pastoral systems, where ruminant husbandry remains a central component of local livelihoods.

Remedies are administered orally or topically, but mostly in combination (81%), with widely reported perceived effectiveness; 85% of informants reported complete recovery (Figure 5). As in human medicine, these outcomes are self-reported and may be influenced by recall bias, placebo effects, or social desirability. These observations align with Hadjadj et al. (2025) in Algeria, who report frequent use (CF = 84.62%) for digestive disorders in ruminants, and Benlarbi et al. (2023), who report using wood tar (Gatran) as an external antiparasitic. This perceived efficacy underscores the cultural trust placed in *J. turbinata*, while highlighting the need for complementary veterinary surveillance, particularly where dosage is not standardized.

Non-medicinal uses

Our results show red juniper is also valued outside traditional medicine, particularly in leather tanning and local handicrafts, especially in Essauira, where its wood is highly sought after. The wood is appreciated for hardness, durability, and resinous fragrance, used in manufacturing various objects and for domestic heating. These observations align with several ethnobotanical and historical studies. Bellakhdar et al. (1991) mention its use as fuel wood and construction material. Boratyński et al. (2024) highlight its quality and its importance in Mediterranean craftsmanship. In Northeastern Morocco, Smaili et al. (2023) report bark exploitation in Jerada to produce tar, while in Algeria, Benlarbi et al. (2023) describe traditional Gatran production through wood distillation, used in craft and in veterinary practices. Recent

studies (Samara et al. 2025) highlight the potential of its essential oils as a green bio-insecticide, opening new ecological perspectives for crop protection and food preservation. Together, these non-medicinal uses complement the medicinal and veterinary applications documented in this study, reflecting the multifunctional role of *J. turbinata* in local livelihood practices and everyday resource use. These findings confirm red juniper as a versatile resource, with energy-related, artisanal, and ecological value extending far beyond traditional pharmacopoeia.

Economic importance of red juniper as a medicinal plant

Results related to sales and demand (Figure 6) indicate that the proportion of informants selling red juniper (13.51%) reflects limited involvement in its commercialization. Supply is obtained mainly from local farmers (77.14%), while personal collection is limited (22.86%) and no cooperatives are involved. This highlights the informal, decentralized nature of the trade, characteristic of non-timber forest product value chains (Belcher and Schreckenber 2007; Shackleton et al. 2011). Given the small number of sellers and the modest monthly volumes traded (1-10 kg), income derived from *J. turbinata* appears to function primarily as a complementary or seasonal revenue source, rather than a major livelihood activity.

Table 7. Citation Frequency (CF), Fidelity Level (FL), and Cultural Importance (CI) of *Juniperus turbinata* in veterinary medicine according to the types of animals treated

Animals treated	Number of citations (U)	CF (%)	FL (%)	CI partial
Cattle	86	16.60	46.74	0.166
Sheep	154	29.73	83.70	0.297
Goats	124	23.94	67.39	0.239
Poultry	4	0.77	2.17	0.008
Equids	30	5.79	16.30	0.058
Felids	2	0.39	1.09	0.004
Total	400	100	-	0.772

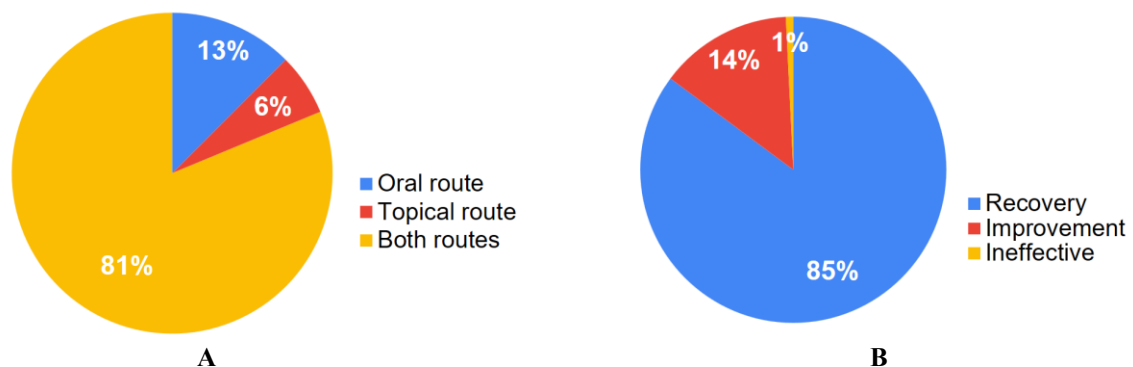


Figure 5. A. Modes of administration and B. Outcomes of red juniper-based veterinary remedies

The Professionalization Index (PI = 3.77/4; i.e., 94.25%) reveals a highly experienced value chain, dominated by sellers active for over ten years (88.6%). This long-standing experience reflects strong stability and traditional know-how but also limited generational renewal. This pattern aligns with the “Sustainable Livelihoods” framework (Walter 2001), where experience is a key economic resilience factor. Comparable patterns of highly experienced but weakly structured value chains have been widely documented for non-timber forest products, particularly medicinal and aromatic plants, in Africa and other regions, and are generally associated with informal market organization (Belcher and Schreckenberg 2007; Shackleton et al. 2011).

Demand is considered moderate to stable by 71.4% of herbalists, and sales occur year-round, reflecting seasonal market stability. However, the absence of cooperatives reduces bargaining power, limits price standardization, and may hinder the transition toward more sustainable or value-added chains. This situation may reflect socio-economic constraints and a weak institutional framework for medicinal plant commercialization, resulting in the persistence of informal trade networks.

Cultural attitudes and conservation practices toward *Juniperus turbinata*

Results show red juniper in Morocco holds limited specific cultural significance, with only a minority attributing particular symbolic value (Figure 7.B). However, it is highly valued for functional and medicinal properties, with most participants considering it as important as, or more important than, other local plants

(Figure 7.C). This aligns with studies highlighting its therapeutic and ecological relevance despite the lack of documented ritual uses (Labiad et al. 2020; Belhaj et al. 2021; Smaili et al. 2023; Jaouad et al. 2025).

Most informants (84%) reported awareness of the importance of conserving red juniper (Figure 7.D), but only under 20% reported implementing sustainable practices (Figure 7.A), revealing a clear awareness-practice gap. This discrepancy may reflect the perception that conservation is mainly driven by the Water and Forest Services, illustrating a top-down approach. This interpretation is consistent with Aubert and Sabir (2013), who describe administrative dominance and limited community involvement in Moroccan forest management, suggesting that further qualitative research is needed.

Conservation proposals converged on three main axes: environmental awareness, strict exploitation regulation, and ecological restoration. Awareness emerged as the most supported measure, aligning with Benabid (2000), who highlights the importance of community participation. Calls for stronger legal frameworks align with recommendations of Salvà-Catarineu et al. (2021), advocating participatory governance and shared legal oversight. Finally, reforestation and natural regeneration proposals confirm ecological approaches advocated by Qarro (2009), recommending local seeds to preserve genetic diversity and forest resilience. Overall, conservation of red juniper is perceived as a shared ecological responsibility requiring combined efforts from institutions and local communities. Reducing the awareness-practice gap will depend on enhanced education, participatory governance, and local empowerment.

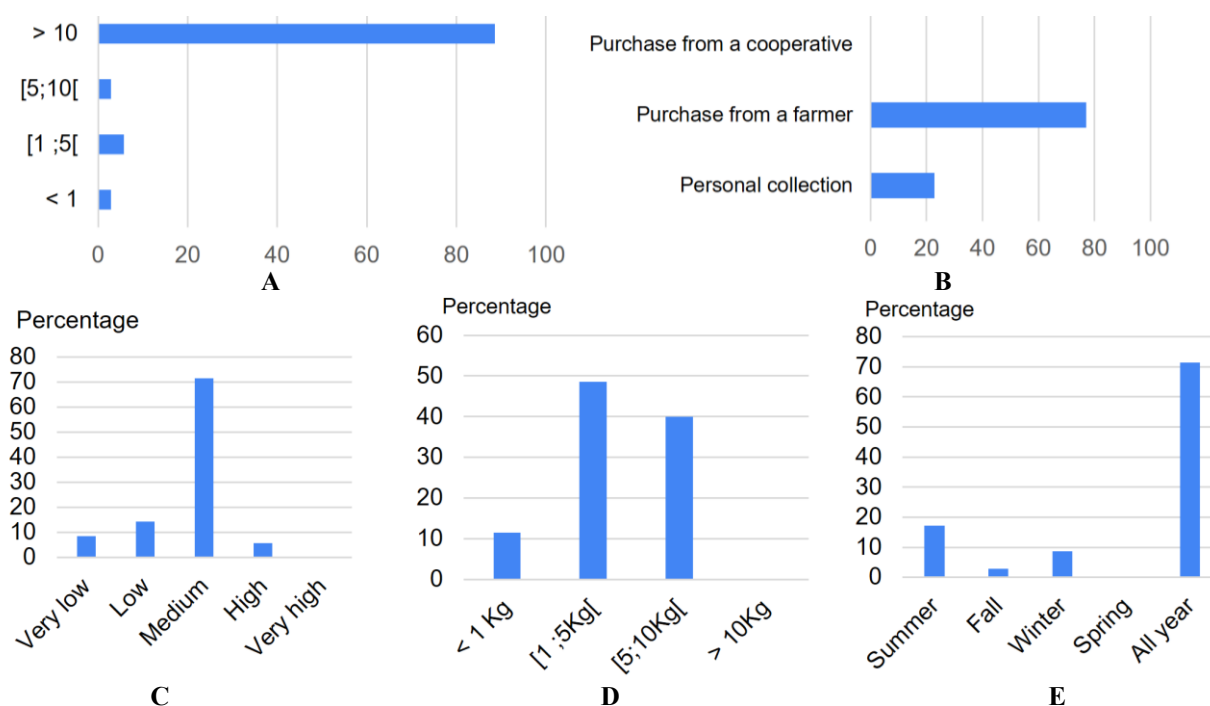
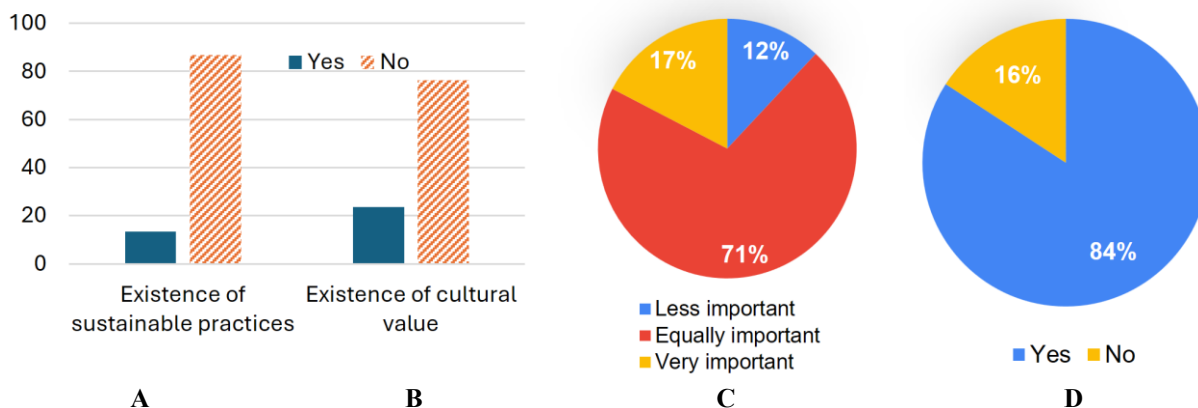


Figure 6. Socio-economic data related to the sale and demand of red juniper. A. Length of experience in selling red juniper, B. Source of red juniper supply, C. Demand for red juniper as a medicinal plant, D. Monthly quantity of red juniper sold, E. Annual selling period of red juniper

Table 8. Association between selected sociological characteristics of informants and the perceived importance of red juniper as a medicinal plant (Chi-square test)

	Distribution	Number of informants	%	The medicinal importance of red juniper			χ^2	p-value			
				Less important	Equally important	Very important					
Sex	Female	234	45.2	24	178	32	6.17	0.046			
	Male	284	54.8	38	188	58					
Age	< 20	50	9.65	6	38	6	10.83	0.094			
	20-40	254	49.03	20	190	44					
	40-60	192	37.07	32	124	36					
	> 60	22	4.25	4	14	4					
Occupation	Farmer	200	38.61	20	150	30	46.98	0.000			
	Teacher	96	18.53	12	62	22					
	Civil servant	14	2.70	8	4	2					
	Herbalist	60	11.58	4	42	14					
	University student	68	13.13	8	44	16					
	Housewife	46	8.88	6	40	0					
	Merchant	16	3.09	2	10	4					
	School student	18	3.47	2	14	2					
	Education level	None	102	19.69	6	76			20	15.44	0.017
		Primary	70	13.51	6	50			14		
Secondary		90	17.37	6	72	12					
University		256	49.42	44	168	44					

**Figure 7.** Results related to cultural attitudes and conservation practices toward *Juniperus turbinata*. A. Existence of sustainable practices implemented within the community, B. Existence of a cultural value attributed to red juniper, C. Importance of red juniper compared to other medicinal plants, D. Awareness of the importance of red juniper conservation.

Chi-square results (Table 8) show that gender ($\chi^2 = 6.17$, $p = 0.046$), occupation ($\chi^2 = 46.98$, $p < 0.001$), and education level ($\chi^2 = 15.44$, $p = 0.017$) significantly influence the perceived importance of red juniper. Women, herbalists, teachers, farmers, and less-educated respondents assign higher value to the species, likely because they remain more closely connected to everyday phytotherapeutic practices and rely more on natural resources. In contrast, younger and more educated individuals, who rely more on modern medicine, attribute lower importance. These patterns suggest that conservation and awareness programs should particularly target younger and highly educated groups to strengthen the intergenerational transmission of traditional knowledge. In contrast, age shows no significant association ($\chi^2 = 10.83$, $p = 0.094$), indicating a relatively uniform perception across age groups.

In conclusion, this ethnobotanical study on *J. turbinata* in Morocco highlights the richness and coherence of traditional knowledge associated with this species. Analyses reveal a high Use Value (UV) and notable Cultural Importance (CI), based primarily on leaves, twigs, and fruits, used predominantly in infusion and decoction. Chi-square tests show that gender, occupation, and education level significantly influence the medicinal importance attributed to the plant, while the choice between traditional, modern, or combined medicine is strongly shaped by age, education, professional activity, place of residence, and length of residence. Beyond documenting uses, this study emphasizes the close interaction between ethnobotanical knowledge, socio-demographic factors, and local ecological contexts. The convergence between local practices and reported pharmacological evidence supports the perceived

effectiveness of *J. turbinata*, while underscoring its high functional and ecological value. In a context of increasing extraction pressure, *J. turbinata* emerges as a species of high ecological and functional value, making its sustainable management a priority for the resilience of Moroccan Mediterranean ecosystems.

However, the study also reveals a clear awareness-practice gap: although most respondents recognize the need to conserve the species, fewer adopt sustainable harvesting practices. Addressing this discrepancy will require targeted environmental education, strengthened participatory governance, and community-based monitoring, rather than reliance on top-down conservation approaches alone.

Several limitations should also be acknowledged, including reliance on self-reported data, limited ecological monitoring, and the cross-sectional nature of the survey. Future research should combine ethnobotanical ecological, and phytochemical approaches, with particular emphasis on validating high-fidelity uses and informing evidence-based conservation and policy interventions.

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