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Insights from a Regional-Level Study of Traditional Plant-Based Treatments for Kidney and Urinary Disorders in Lebanon

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ABSTRACT

Kidney and urinary disorders are globally prevalent conditions with significant health and socio-economic impacts, often requiring comprehensive and culturally adapted healthcare approaches. In Lebanon, numerous plant species are utilized in ethnopharmacological practices for treating renal and urinary ailments. This study aimed to systematically document and analyze the traditional use of plants in Lebanese communities for kidney and urinary disorders, focusing on specific plant parts, origins, preparation methods, and regional variations. Data were collected over nine years from 310 informants across 26 districts, resulting in the identification of 289 plant species from 73 families. Using the Consensus and Fidelity Level for Ethnobotanical Studies (CONCEFS) guidelines, we employed the Relative Frequency of Citation, Use Value, and Relative Importance Index metrics to assess each plant's cultural significance and medicinal versatility. The findings indicate structured usage patterns, with high RFC scores for plant parts like aerial parts and roots and preparation methods such as decoction and infusion, particularly for diuretic and urinary tract infections. Indigenous and cultivated plant species exhibited the highest RFC scores, underscoring a reliance on local resources. The Chi-Square Test of Independence confirmed significant non-random associations between plant characteristics and medical conditions, reflecting culturally embedded preferences and practical efficacy. This research highlights the depth of traditional knowledge in Lebanese communities, offering insights into region-specific practices that could inform future pharmacological studies and conservation efforts. This study underscores the potential for integrating culturally relevant treatments into contemporary healthcare for kidney and urinary disorders.

Keywords: Kidney disorders, Urinary disorders, Traditional medicine, Anthropology, Ethnopharmacology.

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SIGNIFICANCE STATEMENT

Traditional medicine plays a vital role in healthcare systems worldwide, particularly in regions with rich ethnopharmacological heritage. Lebanon's diverse flora has long been utilized in treating kidney and urinary disorders, yet systematic documentation of these traditional practices remains limited. This study, based on extensive fieldwork across 26 Lebanese districts over nine years, identifies 289 plant species used for renal and urinary ailments. By employing ethnobotanical metrics such as the Relative Frequency of Citation and Use Value, we highlight culturally significant plants and their therapeutic applications. Our findings underscore structured usage patterns, emphasizing indigenous and cultivated species, as well as preparation methods like decoction and infusion. The statistical validation of plant-disease associations further supports the pharmacological relevance of these remedies. This research preserves Lebanon's ethnomedical knowledge while providing a foundation for integrating traditional practices into modern nephrotherapy, offering sustainable healthcare solutions and biodiversity conservation.

INTRODUCTION

Kidney and urinary disorders represent a significant global health burden, affecting millions and placing considerable strain on healthcare resources due to their chronic and often recurrent nature (Irek et al. 2018; Jager et al. 2019). These conditions encompass a spectrum of disorders, including enuresis (ENU), kidney infections (KIN), kidney stones (KST), urinary retention (URE), and urinary tract infections (UTIs). Each disorder presents distinct challenges that range from immediate, acute discomfort to chronic, long-term complications that can severely impact a patient's quality of life and necessitate ongoing medical intervention. ENU, or involuntary urination, while often associated with pediatric cases, can extend into adulthood, contributing to psychological distress and social stigma (Graham and Levy 2009). This condition often requires a combination of behavioral therapies, medical treatments, and lifestyle adjustments to manage effectively (Baskoro et al. 2024). KIN, including nephritis and nephropathy, are serious conditions that progress to chronic kidney disease if untreated, increasing the risk of dialysis or kidney transplantation. KST (renal lithiasis) are also particularly burdensome due to their high recurrence rate and the potential for severe pain, urinary blockages, and infections, necessitating timely and effective treatment (Shastri et al. 2023). URE and UTIs further complicate urinary health; retention can lead to bladder damage and kidney impairment if not properly managed, while UTIs pose risks of complications, especially in vulnerable populations (Hosseinpour et al. 2023). Diuretics (DIU) play a crucial role in managing kidney and urinary disorders by promoting urine production, which assists in flushing out the urinary system and reducing fluid retention (Bell and Mandalia 2022). Increased urine output facilitates the removal of excess sodium and water from the body, which helps regulate fluid balance and blood pressure. The mechanism involves reducing the reabsorption of sodium in the renal tubules, which in turn decreases water reabsorption due to osmotic gradients, leading to increased urine excretion (Bell and Mandalia 2022). By minimizing fluid overload and promoting better fluid regulation, diuretics provide significant benefits in chronic kidney disease, where they help manage hypertension, reduce fluid-related stress on the kidneys, and improve overall kidney function (Vasavada and Agarwal 2003).

In Lebanon, renal and urinary disorders reflect global trends while presenting unique regional challenges. Factors contributing to the high incidence of these disorders include dietary habits rich in salt and protein, genetic predispositions, and a hot climate that heightens the risk of dehydration, a significant factor in kidney stone formation (Nasreddine et al. 2014). Additionally, Lebanon's high rates of hypertension and diabetes contribute to the prevalence of chronic kidney diseases and related disorders (Matar et al. 2015). The country's healthcare system faces added challenges due to economic difficulties, which affect the availability and accessibility of advanced treatments and preventive care. This economic situation has led to disparities in patient care, with urban centers generally having better access to specialized nephrology services than rural areas, often resulting in delayed diagnoses and insufficient management of these conditions. Furthermore, structural barriers to healthcare access—including the high cost of conventional medicines, geographic distance from medical facilities, and limited healthcare infrastructure-have created disparities in medical care availability across different populations. In many rural and economically disadvantaged communities, traditional and folk medicine systems function not merely as alternatives to conventional care, but as primary-and often comprehensive-healthcare frameworks that have been culturally embedded for generations. These systems represent autonomous bodies of medical knowledge that operate alongside, rather than simply in the absence of, formal biomedical services. While economic factors do influence healthcare choices, the continued reliance on traditional medicine reflects a complex interplay of cultural preferences, historical continuity,

demonstrated efficacy in local contexts, and practical accessibility-rather than economic necessity alone (Hani et al. 2022).

This study is grounded within an Ethnomedical Framework, which conceptualizes traditional health knowledge as culturally constructed systems for understanding, diagnosing, and treating illness, often integrating medicinal plants and local healing practices (Kleinman 1980; Foster and Anderson 1978; Nichter 1992). In parallel, the study draws upon an Ethnobiological Framework, which emphasizes the dynamic interactions between people and plants, integrating both ecological availability and culturally informed knowledge systems to explain patterns of plant use (Gaoue et al. 2017). Given the diverse geographic and environmental conditions across Lebanon, plant selection is expected to reflect both cultural knowledge and ecological accessibility. Traditional medicinal knowledge is not random; rather, it accumulates over generations through empirical observation and collective trial-and-error within communities. Consequently, systematic preferences emerge regarding which plant parts, preparation methods, or species are most effective for treating particular disorders. Such consistent patterns are expected to be detectable when studying culturally embedded healthcare practices.

Specifically, this study draws upon several hypotheses proposed within ethnobotanical literature to explain medicinal plant selection patterns. The Availability Hypothesis suggests that more abundant and accessible plants are more likely to be utilized for therapeutic purposes (Phillips and Gentry 1993; Gaoue et al. 2017). Similarly, the Ecological Apparency Hypothesis proposes that visible and ecologically dominant species are more commonly incorporated into traditional medicinal systems (Phillips and Gentry 1993). Moreover, the Cultural Keystone Species Concept highlights that certain plant species may attain exceptional cultural importance, serving as critical elements within the health practices and identity of a community (Garibaldi and Turner 2004). These theoretical perspectives provide a structured foundation for interpreting the patterns of plant use observed in the study and for evaluating the cultural and ecological factors influencing traditional medicinal practices related to kidney and urinary health. Additionally, these frameworks provide useful tools for interpreting how cultural and ecological variations shape regional medicinal practices and preferences for different plant origins. By extending ethnobiological and ethnomedical perspectives to spatial and taxonomic patterns, this study explores how traditional pharmacopoeias reflect biocultural adaptation across Lebanon's diverse environments.

Traditional remedies for renal and urinary disorders remain deeply rooted in Lebanese culture, drawing on a rich history of herbal medicine and natural therapies passed down through generations. These remedies rely on locally available plants and are often incorporated into daily life as preventive and therapeutic practices. The importance of traditional medicine in Lebanon is multifaceted, shaped by cultural heritage, biodiversity, and economic considerations. In rural areas, where access to modern healthcare may be limited, traditional remedies offer a cost-effective, accessible solution for managing common renal and urinary issues (Hani et al. 2022). Lebanon's diverse geography and climate create a range of ecosystems that support a rich botanical diversity, forming a "natural pharmacy" that supplies Lebanese communities with various plants with diuretic, anti-inflammatory, and detoxifying properties. This botanical abundance has historically enabled Lebanese practitioners to develop remedies tailored to specific health needs, cultivating a deep knowledge of natural treatments suited to the local environment (Kallassy 2017). Interestingly, Lebanon's remarkable ecological heterogeneity - spanning coastal plains, mountainous zones, and arid valleys - promotes significant regional variation in plant availability. These environmental differences, combined with distinct cultural traditions across districts, are expected to shape regional patterns of medicinal plant selection and application (Baydoun et al. 2015). In a contemporary context, traditional remedies in Lebanon are valued not only for their perceived effectiveness but also as part of a global shift toward holistic and plant-based healthcare. This heritage of traditional medicine remains integral to Lebanese healthcare, bridging ancient practices and modern needs, and offering valuable insights into managing renal and urinary health in ways that are culturally relevant, ecologically sustainable, and economically feasible (Hani et al. 2022). Furthermore, this study provides empirical evidence that critically engages with the Ethnomedical and Ethnobiological frameworks by demonstrating how cultural significance and ecological availability jointly structure medicinal plant use for renal and urinary health. The patterns observed are not limited to Lebanon and offer comparative insights applicable to traditional medical systems in other regions. In doing so, the research extends the theoretical understanding of human-plant healthcare relationships and offers a quantitative approach for cross-cultural ethnobotanical analysis.

Based on these theoretical foundations, this study aims to investigate the following questions: (1) Which plant species are culturally significant in the traditional treatment of kidney and urinary disorders in Lebanon? (2) How do ecological availability and perceived therapeutic value influence the selection of these species? This study examines whether plant use patterns reflect non-random selection processes shaped by

ecological availability and visibility, as suggested by the Availability and Ecological Apparency Hypotheses, while also independently exploring the role of cultural factors in medicinal plant selection. Specifically, we expect that species with greater ecological presence and accessibility will exhibit higher relative frequency of citation (RFC), use value (UV), and relative importance (RI) indices. These indices not only reflect ecological factors but also serve as proxies for perceived therapeutic value. High RFC indicates widespread recognition of a plant's medicinal use, while high UV reflects its versatility across therapeutic contexts. RI combines these aspects, offering a comprehensive measure of cultural significance. Thus, we expect that plant selection is influenced by an interplay between ecological availability and culturally mediated perceptions of therapeutic effectiveness. In this context, we interpret "selection" as the outcome of a culturally embedded process shaped by intergenerational knowledge transmission, perceived efficacy, and ecological familiarity. High values in RFC and UV reflect the cumulative effect of this process-indicating which species have become trusted and widely adopted over time. These indices therefore function not only as descriptive tools but as proxies for selection dynamics within traditional medical systems.

Despite a growing body of ethnobotanical research on Lebanon's medicinal flora, a notable gap remains in studies focusing specifically on plants used for kidney and urinary disorders. This study seeks to address this gap by systematically documenting the traditional knowledge of rural healers and herbalists regarding plants used to treat these conditions. Conducted over a nine-year period, this ethnopharmacological field study not only records traditional practices but also explores the pharmacological potential of these plants, laying the groundwork for their possible applications in modern medicine. The importance of this research is threefold: by focusing on kidney and urinary disorders, it sheds light on remedies that are culturally significant and potentially effective for addressing common health issues in Lebanon; by preserving and systematically documenting the knowledge of local healers, it contributes to safeguarding Lebanon's ethnomedical heritage, which faces threats from modernization; and by highlighting the therapeutic value of native plants, it emphasizes the need to conserve Lebanon's rich biodiversity, which supports traditional practices and holds promise for future medical research and drug discovery. This study thus bridges traditional and modern approaches, advocating for a holistic, sustainable approach to healthcare that values cultural knowledge and environmental conservation.

MATERIAL AND METHODS

Ethnobotanical Field Study

This study was conducted between 2011 and 2020 in rural and mountainous regions of Lebanon, where traditional healers and herbalists continue to play a significant role in healthcare. Informed consent was obtained from all participants prior to the interviews, in accordance with ethical standards set by the International Society of Ethnobiology (ISE) and the Convention on Biological Diversity (CBD). At the time of the study, Lebanon did not maintain a formal permitting system specifically governing ethnobotanical research involving non-endangered native plant species or traditional medicinal knowledge. Nonetheless, ethical compliance was ensured through verbal approvals from local municipal authorities and close coordination with community leaders. Participants were informed of the aim of preserving traditional knowledge and were provided with copies of the results to benefit their communities. Compensation for their time was offered in the form of community-based knowledge-sharing workshops. Study Design.

The study focused on identifying medicinal plants used for kidney and urinary disorders. A purposive sampling strategy was employed, selecting participants based on their knowledge and practice as traditional healers, herbalists, or knowledgeable elders. Interviews were conducted in Arabic, the native language of all participants, and local plant names were documented. The fieldwork was conducted in 106 different villages located in 26 districts across Lebanon deliberately selected to capture a representative diversity of ecological and cultural landscapes associated with traditional plant-based remedies for kidney and urinary ailments (Supplementary Material). The villages included both densely populated urban centers such as Beirut and Tripoli, as well as remote and sparsely populated mountainous areas such as Bsharri and Hermel. Community size in these regions is highly variable, reflecting Lebanon's diverse settlement patterns. While urban districts may contain tens of thousands of residents, rural villages typically range between a few hundred and several thousand inhabitants. Based on national demographic data, the majority of villages surveyed in this study are estimated to host populations between 1,000 and 5,000 individuals. This variation reflects Lebanon's socioecological diversity and supports the representativeness of the plant-related knowledge held by local communities documented in the present work. These communities represent Lebanon's cultural and socioecological diversity, ranging from remote agro-pastoralist mountain populations to peri-urban and coastal groups involved in mixed economic activities. Subsistence patterns vary accordingly, with

rural districts relying on traditional agriculture, small-scale livestock rearing, and wild plant gathering, while urban areas integrate wage labor and market-based practices.

The studied districts span four primary ecological environments, each offering distinct climatic, topographic, and botanical conditions that have historically shaped local medicinal practices (Figure 1). The Coastal Plain, encompassing Beirut, Tripoli, Tyre, Sidon, Batroun, Jbeil, Koura, and parts of Miniyeh-Danniyeh, is characterized by a Mediterranean climate with mild, wet winters and hot, dry summers, supporting rich herbaceous and shrubby vegetation often accessible year-round. The Mount Lebanon Range, including Aley, Baabda, Chouf, Bsharri, Jezzine, Bint Jbeil, Nabatiyeh, Marjeyoun, Keserwan, Matn, Zgharta, and portions of Batroun, Jbeil, and Miniyeh-Danniyeh, features rugged mountainous terrain, cooler temperatures at elevation, and extensive forest cover, notably cedar, oak, and pine, which traditionally provided communities with a wide array of therapeutic plant species. The Beqaa Valley, comprising Zahleh, Baalbek, and Western Beqaa, represents a semi-arid inland plain characterized by continental climatic influences, reduced annual precipitation, and intensive agricultural activity, where medicinal knowledge is closely tied to drought-resistant and cultivated species. The Anti-Lebanon Mountains, including Hermel, Rashaya, and Hasbaya, consist of high-altitude arid uplands, with sparse rocky soils supporting hardy vegetation adapted to water scarcity. By intentionally sampling districts across these diverse ecological zones, the study aimed to capture not only a broad range of botanical resources but also the variability in traditional medicinal knowledge systems that have evolved in response to environmental constraints and resource availability (Figure 1).

Moreover, the classification of plant origin categories was carefully designed to reflect both ecological status and ethnobotanical relevance, ensuring that interpretations of use patterns are grounded in culturally and biologically meaningful distinctions. For this purpose, five origin categories were defined based on standard ecological and ethnobotanical criteria. Indigenous (IND) species refer to plants native to Lebanon that occur naturally across the region and neighboring territories, representing taxa integrated into local ecosystems without human introduction. Endemic (END) species, by contrast, are native and geographically restricted to Lebanon, thus holding potential significance as culturally and ecologically unique resources within traditional knowledge systems. Cultivated (CUL) plants comprise taxa actively propagated and maintained by humans within agricultural or domestic contexts, regardless of whether they are native or introduced, emphasizing the role of human agency in their availability and use. Imported (IMP) species include non-native plants not cultivated locally, but introduced via historical or contemporary trade and integrated into traditional practices through intercultural exchange. Finally, Naturalized (NAT) species refer to historically introduced taxa that have established self-sustaining populations in wild habitats, becoming ecologically integrated and accessible for traditional uses. This categorization was based on a synthesis of information from national floristic references (e.g., Tohmé and Tohmé 2007), the Euro+Med PlantBase, and consultations with local botanical experts. Field observations were also employed, particularly to confirm the cultivation or naturalization status of species within the study areas.

These distinctions were adopted to disentangle the influence of ecological availability, cultural preferences, and historical plant exchange on the structuring of traditional pharmacopoeias. By enabling differentiation between local and introduced resources, as well as between human-managed and wild-harvested plants, this classification framework provides critical resolution for interpreting structured patterns in medicinal plant use within Lebanese ethnomedical systems.

Data Collection

Participants (N=310) aged between 30 and 80 were interviewed about their knowledge of medicinal plants, including the local names, parts of the plant used, preparation methods, origin of the plant, and the specific conditions particularly those pertaining to the kidney and urinary systems (Supplementary Material). Across the 26 districts, interviews were conducted in 2 to 6 communities per district, totaling 106 communities nationwide. Within each community, 2 to 4 knowledgeable individuals were selected for interviews, based on their local recognition as experts in traditional plant use. Community selection aimed to reflect ecological variation, cultural distinctiveness, and the presence of reputed healers or elders, ensuring both environmental and sociocultural representativeness. Identification of participants was conducted through informal consultations with respected community members, including elders and health workers, who provided input on individuals considered to hold substantial ethnomedical knowledge. This sampling strategy ensured inclusivity and participatory validation across Lebanon's diverse socioecological settings. "Use reports" were collected, quantifying how many participants mentioned a particular plant for a specific condition. The frequency of these reports was used to calculate the importance of each plant species in treating kidney and urinary disorders.

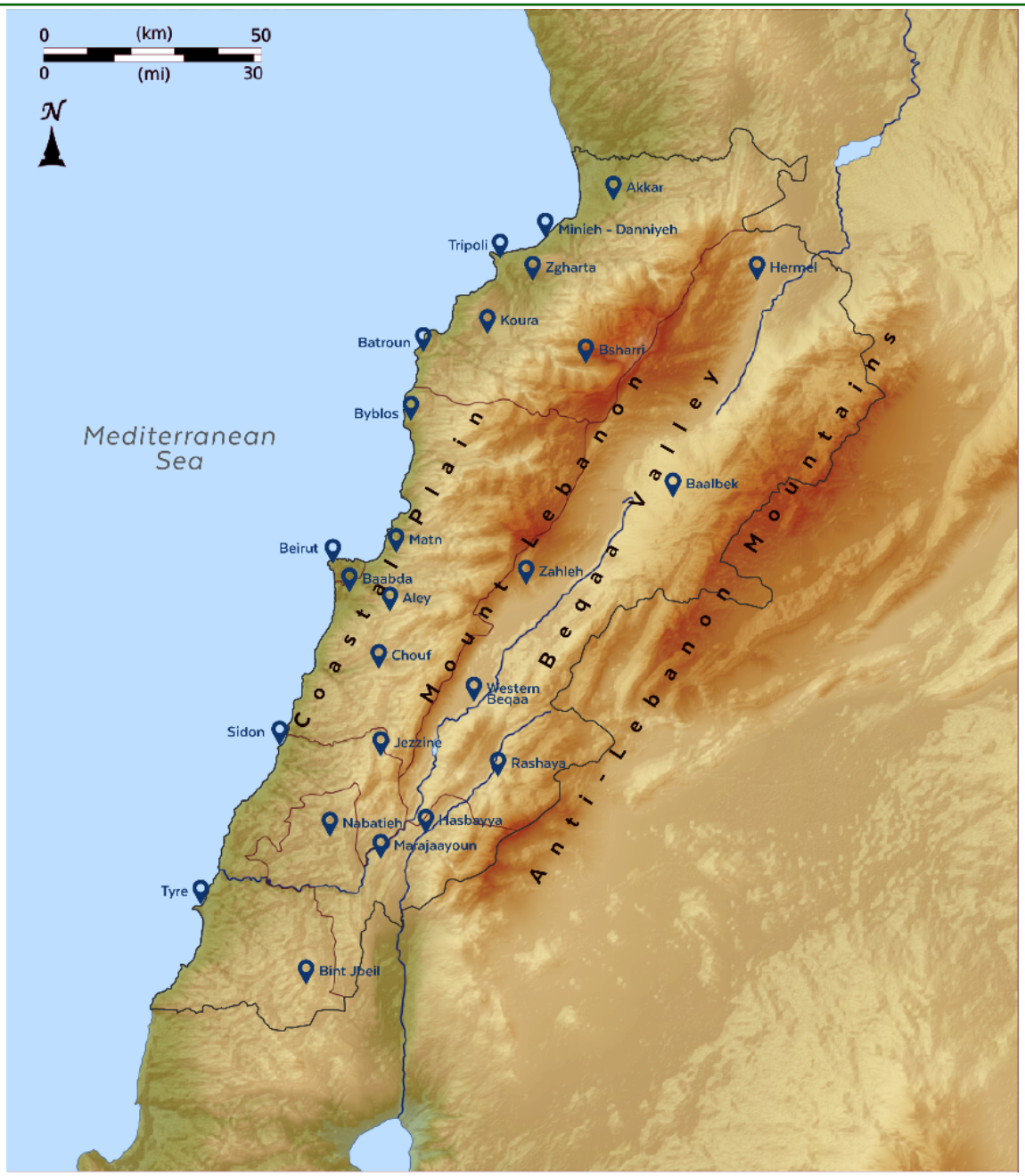

Figure 1. Map of Lebanon showing the 26 districts included in the ethnobotanical survey of medicinal plant use for kidney and urinary disorders. The study sites are distributed across Lebanon's diverse ecological regions, including the Coastal Plain (e.g., Beirut, Tripoli, Byblos, Tyre), Mount Lebanon (e.g., Baabda, Aley, Bsharri, Matn), the Beqaa Valley (e.g., Zahleh, Western Beqaa, Baalbek), and the Anti-Lebanon Mountains (e.g., Hermel, Rachaya, Hasbaya) Base map adapted from: Eric Gaba (Wikimedia Commons user: Sting) and NordNordWest, Wikimedia Commons (`https://commons.wikimedia.org/wiki/File:Lebanon_physical_blank_map.png`). Used under the Creative Commons Attribution-Share Alike 3.0 Unported license.

Botanical Identification

Plant samples were collected in triplicates and identified on the basis of the "Nouvelle flore du Liban et de la Syrie" (Mouterde et al. 1966; Greuter and Mouterde 1970; Mouterde et al. 1983) following the new phylogenetic classification APG II (Angiosperm Phylogeny Group 2003) to update the families mentioned. After checking the plant names with "World Flora Online" (`www.worldfloraonline.org`), the voucher specimens were prepared and deposited at

the Department of Agriculture and Food Engineering, Holy Spirit University of Kaslik, Jounieh, Lebanon.

Data analysis

In this study, statistical methods based on the CONCEFS (Consensus and Fidelity Level for Ethnobotanical Studies) guidelines were employed to evaluate the cultural significance and medicinal diversity of plants used for renal and urinary disorders in Lebanon. RFC was calculated as RFC = FC/N, where FC represents the number of participants who cited a given plant, and N is the total number of participants. This metric reflects the frequency of mention across all informants and provides a standardized measure of each plant's cultural prominence at the regional level. Higher RFC values suggest broader recognition and shared ethnomedical knowledge across communities. The UV, calculated as UV = $\sum$Ui/N (where Ui represents the number of uses cited for a plant), measures each plant's versatility across health conditions. To provide an integrated assessment, the RI was derived by averaging RFC and UV, reflecting both cultural significance and medicinal versatility.

To explore patterns of medicinal plant selection, RFC values were calculated separately for multiple plant attributes, including (i) part of the plant used, (ii) plant origin, (iii) district of use, and (iv) preparation method. For each of these attributes, cross-tabulations were constructed comparing the relative frequencies of citation across different categories and different medical conditions. Subsequently, Chi-Square Tests of Independence were applied to these cross-tabulations to statistically assess whether observed associations between plant attributes and specific medical conditions were significant or simply due to random variation. The categorical data were organized into contingency tables where rows represented different plant attribute categories and columns represented the distinct kidney and urinary disorders investigated. Expected frequencies were computed under the assumption of independence, and deviations from expectation were tested for significance. Highly significant p-values ($p < 0.001$) indicated strong non-random and culturally meaningful relationships between plant characteristics and their therapeutic applications.

RESULTS AND DISCUSSION

Ethnobotanical Significance and Use Diversity of Medicinal Plants

This study indicates that a total of 289 plant species, spanning 73 distinct families, continue to play an active role in Lebanese folk medicine for the treatment of kidney and urinary disorders. Among these 73 families, certain groups emerged as particularly prominent in traditional healthcare practices. The Asteraceae family was the most represented, with 49 species, followed by Apiaceae (20 species), Rosaceae (17 species), and Brassicaceae (16 species). Other significant families included Fabaceae and Lamiaceae, each with 15 species, Poaceae with 13 species, and Amaranthaceae with 10 species. This distribution highlights the botanical diversity leveraged in Lebanon's ecological knowledge for addressing renal and urinary health concerns (Supplementary Material).

However, traditional medicinal knowledge is not arbitrary; rather, it reflects structured and culturally embedded selection processes. As summarized in Table 1, the most culturally significant species — indicated by higher RI scores — demonstrate clear and consistent pharmacological rationales.

Notably, plants such as *Matricaria aurea*, *Artemisia judaica*, and *Hypericum perforatum* emerged as cultural prominent species, characterized by both high community recognition and diverse therapeutic applications. The table further illustrates how species with strong antioxidant, anti-inflammatory, diuretic, and nephroprotective activities dominate traditional remedies, reflecting a therapeutic focus tailored to the pathophysiology of renal and urinary ailments. This pattern resonates with the Ethnomedical Framework, where empirical efficacy and cultural validation converge to shape knowledge transmission. Additionally, the prominence of indigenous and cultivated species in the table supports the Availability Hypothesis, suggesting that ecological accessibility remains a key determinant of medicinal plant use. Similarly, the frequent use of ecologically conspicuous taxa, including widespread herbs and shrubs, aligns with the Ecological Apparency Hypothesis, indicating that visible and abundant plants are preferentially integrated into traditional pharmacopoeias. Together, these findings reveal that medicinal plant selection for kidney and urinary disorders in Lebanon is shaped by an interplay between ecological factors and cultural significance. By providing a concise synthesis of ethnobotanical indices and pharmacological evidence, these results not only enhance clarity but also empirically substantiate the existence of non-random, theory-driven patterns in traditional healthcare systems (Figure 2).

Table 1. Summary of Culturally Significant Medicinal Plant Species for Kidney and Urinary Disorders in Lebanon, Including Ethnobotanical Indices, Key Phytochemicals, and Pharmacological Activities.

Species	Relative Frequency of Citation (RFC)	Use Value (UV)	Relative Importance (RI)	Key Phytochemicals	Pharmacological Activities	References
Matricaria aurea (Loefl.) Boiss.	31	1000	515	Flavonoids (apigenin and luteolin), essential oils (-bisabolol and azulenes)	Anti-inflammatory, antioxidant, and antimicrobial properties	Alkheder et al. 2024
Artemisia judaica L.	38	600	319	Monoterpenes (piperitone), sesquiterpenes, flavonoids (luteolin, apigenin), ethyl cinnamate, camphor	Antioxidant, anti-inflammatory, antibacterial, hypoglycemic	Alsharif et al. 2024; Awad et al. 2022
Hypericum perforatum L.	569	54	312	Flavonoids (hyperoside, quercitrin, rutin), hypericin, hyperforin	Antioxidant, anti-inflammatory, nephroprotective, anti-urolithiatic, anti-fibrotic	Liu et al. 2021; Kennedy and Wightman, 2011
Alhagi maurorum Medik.	31	500	265	Flavonoids, tannins, triterpenes, glycosides	Anti-urolithiatic, nephroprotective, antioxidant, diuretic	Ammar et al. 2024; Srivastava et al. 2014; Alkhafaji & Alharbi, 2024
Sideritis perfoliata L.	31	500	265	Essential oils, terpenes, flavonoids, iridoids, phenolic acids	Antispasmodic, anti-inflammatory, antioxidant, diuretic	Deveci et al. 2019; Sarikurkcu et al. 2020
Umbilicus rupestris (Salisb.) Dandy	31	500	265	Anthocyanins, bufadienolides, saponins, coumarins, carotenoids, sitosterols, tocopherols, lectins	Antioxidant, nephroprotective, regulates urinary electrolytes	Devbhuti et al. 2008; Lyda et al. 2019
Apium graveolens L.	446	69	258	Apigenin	Antioxidant, nephroprotective, reduces inflammatory markers	Barus et al. 2024; Razzuqi et al. 2011
Urtica urens L.	69	444	257	Polyphenols, terpenoids	Anti-urolithiatic, antioxidant, anti-inflammatory	Al-Shammari, 2019
Glycyrrhiza glabra L.	454	51	252	Glycyrrhizin, glycyrrhetinic acid, flavonoids	Anti-apoptotic, nephroprotective, modulates fluid retention	Basist et al. 2022; Sabbadin et al. 2019
Rubia tenuifolia d'Urv.	54	429	241	Anthraquinones	Diuretic, antioxidant, anti-urolithiatic	Singh et al. 2004; Blömeke et al. 1992

Associations between Plant Part Usage and Medical Conditions

The analysis of plant part usage across medical conditions revealed a nuanced pattern of traditional medicinal practices, underscored by a significant association between specific plant parts and particular health treatments (Supplementary Material). This study identified distinct trends, with some plant parts, like aerial parts (APA), exhibiting high RFC values (e.g., RFC = 1.00 for DUI), indicating widespread cultural recognition and trust in their effectiveness for common conditions (Figure 3). These findings align with studies conducted in Urmia, Northwest Iran, where aerial parts were the most frequently cited plant components, comprising up to 41.1% of remedies for the treatment of urinary calculi. The rich composition of flavonoids and saponins in these parts contributes to their diuretic effects and ability to inhibit stone crystallization (Bahmani and Zargaran 2015). Similar results have been observed in Shiraz, another region in Iran, further emphasizing the role of aerial parts in dissolving kidney stones and mitigating inflammation (Bahmani et al. 2016). Additionally, research on Lespedeza capitata and Vernonia cinerea, belonging to the Fabaceae and Asteraceae families respectively, has demonstrated the nephroprotective, hypoazotemic, and anti-inflammatory properties of aerial parts. These effects make them effective in managing kidney and urinary disorders, including chronic renal failure and nephritis (Zaychenko et al. 2024; Khan et al. 2022). In contrast, less frequently cited plant components, such as acorns (ACO), with an RFC of 0.06 for diuretic use (DIU), appear to have more specialized or regionally constrained applications, likely influenced by specific cultural practices or limited availability (Figure 3). Acorns exhibit unique therapeutic potential, characterized by their antimicrobial, anti-inflammatory, and antioxidant properties, which have been shown to be effective in managing kidney stones and urinary infections (Akcan et al. 2017; Söhretoglu et al. 2007). For example, the acorns of Quercus leucotrichophora are particularly rich in tannins, which provide protective effects against inflammation and oxidative damage, thereby supporting the management of urinary infections (Akhtar et al. 2013; Moriyama et al. 2009).

The highly significant Chi-Square result (χ^2 $(95, N = 310) = 1704.38$, $p < 0.001$) validates these observed associations as non-random, underscoring a systematic reliance on particular plant parts for specific ailments within Lebanese folk medicine. Plant parts with moderate RFC scores, such as bulbs and roots, suggest roles in more targeted or localized therapies, while those with low RFC scores may serve niche applications within certain communities. Roots, for example, displayed an RFC of 0.32 for kidney stones (KIN) and 0.35 for urinary retention (URE) (Figure 3). Previous ethnobotanical studies have demonstrated that the use of these parts in managing kidney-related disorders is due to their high concentrations of bioactive compounds, including alkaloids and terpenoids (Maroyi, 2013; Singh and Rawat 2011). Nevertheless, the overharvesting of roots poses sustainability concerns that threaten the survival of these medicinal plants (Flatie et al. 2009). This issue arises because root harvesting often kills the plant, and many of these root-harvested species are slow-growing and require long regeneration periods, further intensifying the risk of depletion when they are overexploited for medicinal purposes. This balance between their pharmacological efficacy and ecological implications underscores their careful application in traditional medicine. On the other hand, leaves (LEA), with high RFC values for DUI (1.00), KIN (0.93), and UTI (1.00), emerged as one of the dominant plant part in Lebanese folk medicine (Figure 3). The literature further supports these results and identifies leaves as one of the most frequently used plant part in traditional medicine globally. For example, studies in Lebanon, Morocco, and Portugal report that the abundance of leaves and ease of collection make them the preferred plant part for diuretics use (Baydoun et al. 2015; Bencheikh et al. 2021; Neves et al. 2009). Similarly, research from Algeria highlights the dominance of leaves in therapeutic recipes for urinary lithiasis, due to their active phytochemical content and sustainable harvesting practices (Taibi et al. 2021). Furthermore, the therapeutic significance of leaves is enhanced by their role as the primary site of photosynthesis and as reservoirs of secondary metabolites, which provide a concentrated source of bioactive compounds for medicinal use (Bhat et al. 2013). This distribution illustrates the diverse roles of plant parts, ranging from universally applied remedies to those reserved for specific conditions, showcasing the adaptability and sophistication within traditional medicine.

Regional Variations in Traditional Medicinal Plant Use for Kidney and Urinary Disorders in Lebanon

The analysis of district-level RFC scores revealed structured and meaningful geographic variability in the traditional use of medicinal plants for kidney and urinary disorders. These patterns reflect the profound ways in which ecological environments and cultural traditions intersect to shape medicinal knowledge systems across Lebanon —an observation consistent with ethnobiological frameworks emphasizing the co-adaptation of traditional knowledge to local socioeco-

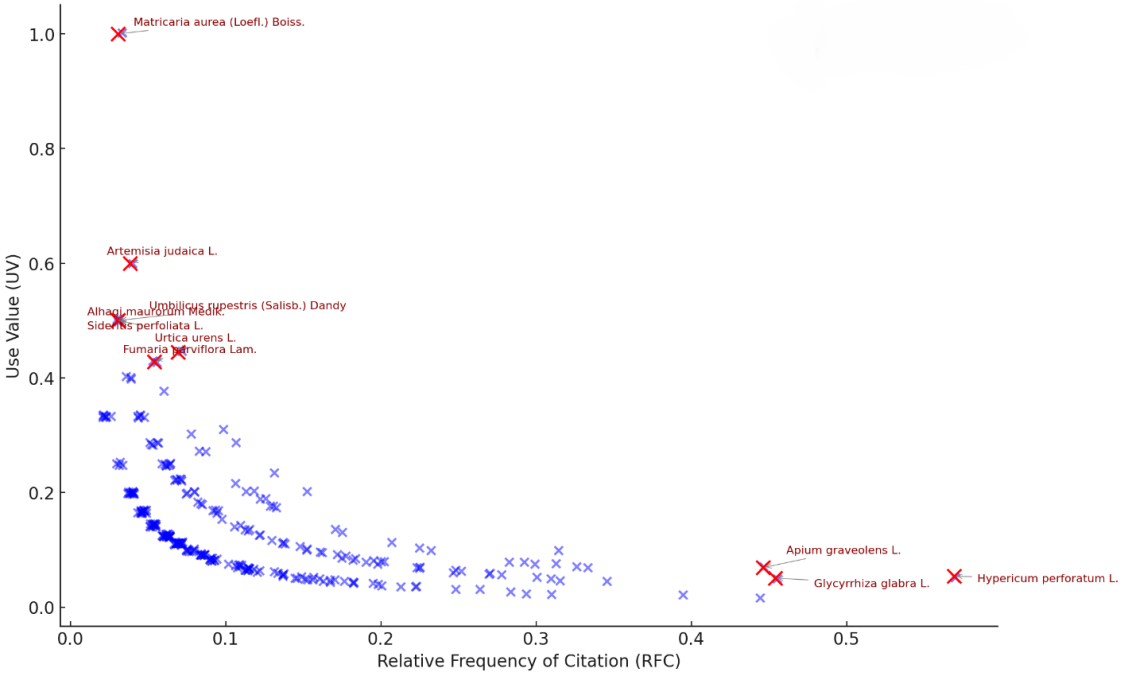

Figure 2. Relationship between Use Value (UV), Relative Frequency of Citation (RFC), and Relative Importance (RI) for Medicinal Plants Used in Kidney and Urinary Disorders in Lebanon. Top 10 Plants with Highest RI Indicated in Red. Analysis of the top-ranking plants by RI reveals two distinct patterns. Some species, such as *Matricaria aurea* ($RFC = 0.031, UV = 1.00$), achieve high RI due to exceptionally high versatility (UV), despite relatively low RFC. In contrast, plants like *Hypericum perforatum* ($RFC = 0.57, UV = 0.05$) attain comparable RI primarily through widespread cultural consensus (high RFC), despite limited therapeutic versatility. This demonstrates that plants can gain significant cultural prominence through different ethnobotanical pathways—either through broad-based recognition across many informants, versatility of medicinal uses, or a balanced combination of both.

logical contexts. Most notably, DIU emerged as the most consistently cited category across districts, underscoring the central role of water balance management and urinary function in local therapeutic traditions. However, the geographic distribution of high RFC values indicates that this knowledge is not evenly spread, but instead reflects adaptations to ecological and cultural contexts.

The Coastal Plain districts—particularly Tripoli, Jbeil, and Sidon—exhibited consistently elevated RFC scores across multiple urological categories, including DIU, UTI, KIN, and KST. Jbeil stands out with maximal RFC values for DIU (1.00), KST (1.00), and UTI (0.72), suggesting a locally embedded therapeutic repertoire that is both broad and condition-specific. Similarly, Tripoli and Sidon show high scores across multiple categories, underscoring a pattern of pharmacological versatility not paralleled in most inland regions. This multidimensional knowledge structure likely reflects a convergence of ecological opportunity and sociocultural permeability. The Mediterranean coastline of Lebanon, with its relatively stable climate, extended growing seasons, and herbaceous plant richness, offers ecological conditions conducive to the sustained availability and apparency of medicinal taxa—factors central to both the Apparency and Availability Hypotheses. Yet ecological explanation alone is insufficient. These coastal zones, particularly Jbeil and Tripoli, have historically functioned as nodes of maritime trade and cultural interchange, in line with what Pieroni and Quave (2005) describe as "hybridized pharmacopoeias" wherein native and introduced species coexist within a dynamic, open medical system. Similar patterns are documented in North African port cities (Bencheikh et al. 2021) where high plant-use diversity corresponds not only to biodiversity but also to intensified cultural exchange. In this light, the coastal ethnopharmacological profiles observed here can be interpreted not as ecologically determined alone, but as products of long-term biocultural integration processes. In contrast, the Mount Lebanon Range exhibits broad medicinal plant use diversity, reflected in slightly lower average RFC values (0.36), even as individual districts like Aley (RFC_DIU = 0.92), Matn (RFC_KST = 0.82), and Keserwan (RFC_DIU = 1.00) demon-

Figure 3. Heatmap of Relative Frequency of Citation (RFC) Scores for Different Plant Parts Used in Treating Kidney and Urinary Disorders Across Medical Conditions in Lebanon.

strate high scores for specific conditions (Figure 4). This pattern suggests that the region's ecological richness—characterized by its forested landscapes, altitudinal variation, and botanical heterogeneity—has facilitated the development of a dispersed and highly specialized ethnopharmacological repertoire. Rather than converging on a narrow set of widely cited plants, as seen in more resource-limited areas, communities in Mount Lebanon appear to draw upon a broader spectrum of species, each tailored to particular renal or urinary disorders. The lower mean RFC, therefore, does not indicate weaker knowledge, but rather a diffusion of citations across a larger pool of culturally recognized remedies. This reflects a more differentiated system of plant selection, likely shaped by sustained intergenerational knowledge transmission and close ecological familiarity with a wide variety of locally available flora. This pattern aligns with observations from mountainous ethnobotanies globally, where environmental heterogeneity and high species turnover support fine-grained therapeutic specialization rather than reliance on a few universally cited remedies (Sá et al. 2024).

The Beqaa Valley presents a distinct ethnobotanical profile, characterized by moderately high average RFC values and prominent condition-specific peaks, particularly in Zahleh (DIU = 1.00; KST = 0.90) and Baalbek (DIU = 1.00). These values underscore a concentrated and ecologically attuned medicinal knowledge system shaped by the region's semi-arid conditions and agricultural context. Unlike the floristically dense forests of Mount Lebanon, the Beqaa's reduced precipitation and continental climate limit spontaneous wild flora diversity, leading to a greater dependence on cultivated and drought-tolerant species. This pattern mirrors findings in other dryland ethnobotanies, where agro-ecological settings promote reliance on resilient, domesticated taxa for urological and nephrological care (Bencheikh et al. 2021; Maroyi 2013). Rather than a broad, undifferentiated pharmacopoeia, the Beqaa profile reflects what might be described as selective intensification: fewer plants cited more frequently, tailored to the most prevalent renal and urinary conditions. This concentration of citations underscores the capacity of traditional knowledge systems to adapt pragmatically to environmental con-

straints and reflects consistent empirical validation of a narrow but effective set of species within local communities (Baydoun et al. 2015; Hani et al. 2022). The Anti-Lebanon Mountains display the most ecologically austere profile among the four regions studied, with the lowest average RFC and a narrower therapeutic scope. Despite these constraints, specific districts such as Rashaya record high RFC values for diuretic use (DIU = 1.00) and kidney stones (KST = 0.77), indicating a focused and functionally resilient ethnopharmacological system. This pattern suggests that in these high-altitude, semi-arid uplands—where vegetation is sparse, rainfall is minimal, and soil quality is poor—communities have developed deeply specialized knowledge around a small set of robust, ecologically adapted plant species. These findings align with global observations in harsh environments, where ecological constraints narrow the range of available species but simultaneously sharpen cultural emphasis on those that are proven to be effective (Bhat et al. 2013; Pardo-de-Santayana et al. 2007). The elevated RFCs for DIU and KST in these settings reflect both ecological necessity—given the higher risk of dehydration-related conditions—and cultural continuity in retaining a small but potent pharmacopoeia. The data suggest that the Anti-Lebanon Mountains do not exhibit a deficit in traditional knowledge, but rather a streamlined system that prioritizes efficacy and ecological fit, where fewer remedies are cited but with high confidence and frequency across informants.

Importantly, the highly significant Chi-Square result confirms that these patterns are far from random. They reflect deeply embedded, ecologically and culturally contingent knowledge systems that have evolved in response to Lebanon's diverse landscapes and localized therapeutic needs. Taken together, these findings demonstrate that traditional medicinal plant use in Lebanon is shaped by a sophisticated interplay between ecological constraints, botanical availability, and culturally transmitted health practices, resulting in a geographically nuanced ethnopharmacological heritage.

Associations between Plant Origins and Medical Conditions

The differential utilization patterns observed across plant origin categories provide empirical validation for the Ethnobiological Framework established in this study, while revealing nuanced interactions between ecological availability and culturally mediated plant selection that extend beyond the basic tenets of the Availability Hypothesis. The dominance of indigenous plants, exhibiting maximal RFC values (1.0) for multiple conditions including DIU and KIN, strongly supports the Availability Hypothesis while simultaneously demonstrating how ecological accessibility becomes embedded within cultural knowledge systems through intergenerational transmission. This pattern aligns with emerging biocultural theory, which posits that indigenous plant knowledge represents not merely opportunistic utilization of available resources, but rather sophisticated co-evolutionary adaptations where human communities and native flora have mutually shaped each other's characteristics over extended temporal scales (Berkes 2008). In Mediterranean contexts, such as those documented in the Aegadian Islands, traditional plant knowledge remains embedded in the memories of elder populations despite modern disruptions, representing biocultural refugia that maintain critical linkages between ecological diversity and cultural practices (La Rosa et al. 2021). Lebanon's positioning within this broader Mediterranean biocultural framework is particularly significant, as the region functions as a biogeographical crossroads where European, Asian, and African floristic elements converge, creating an exceptionally rich botanical substrate for traditional medicinal knowledge development.

The remarkable integration of cultivated plants (RFC = 1.0 for DIU, 0.92 for KST) exemplifies the medicinal plant domestication that reveals sophisticated human-plant relationships that transcend the basic tenets of the Ecological Apparency Hypothesis. Unlike wild harvesting, cultivation represents a deliberate human intervention in plant availability, suggesting that Lebanese traditional medicine practitioners may have identified species with superior therapeutic properties and invested significant effort to ensure their consistent supply. This cultivation pattern reflects a sophisticated indigenous understanding of the relationship between plant genetics, environmental conditions, and therapeutic potency—knowledge systems that parallel findings from contemporary ethnobotanical research across diverse cultural contexts, where domestication of medicinal plant species represents a primary conservation strategy (Mbongwa et al. 2021). The high cultural significance of cultivated medicinal plants in Lebanese traditional medicine thus represents not merely convenience-based selection, but rather evidence of advanced ethnoecological management systems that actively enhance therapeutic landscapes through deliberate intervention in plant evolution and ecosystem composition.

Over and above, the substantial utilization of imported plants (RFC = 1.0 for DIU, 0.57-0.74 across other conditions) reveals the dynamic, adaptive capacity of Lebanese traditional medicine to integrate exotic botanical knowledge. This integration follows predictable ethnopharmacological patterns: plants with pronounced therapeutic effects, morphological familiarity, or existing cultural associations in trading

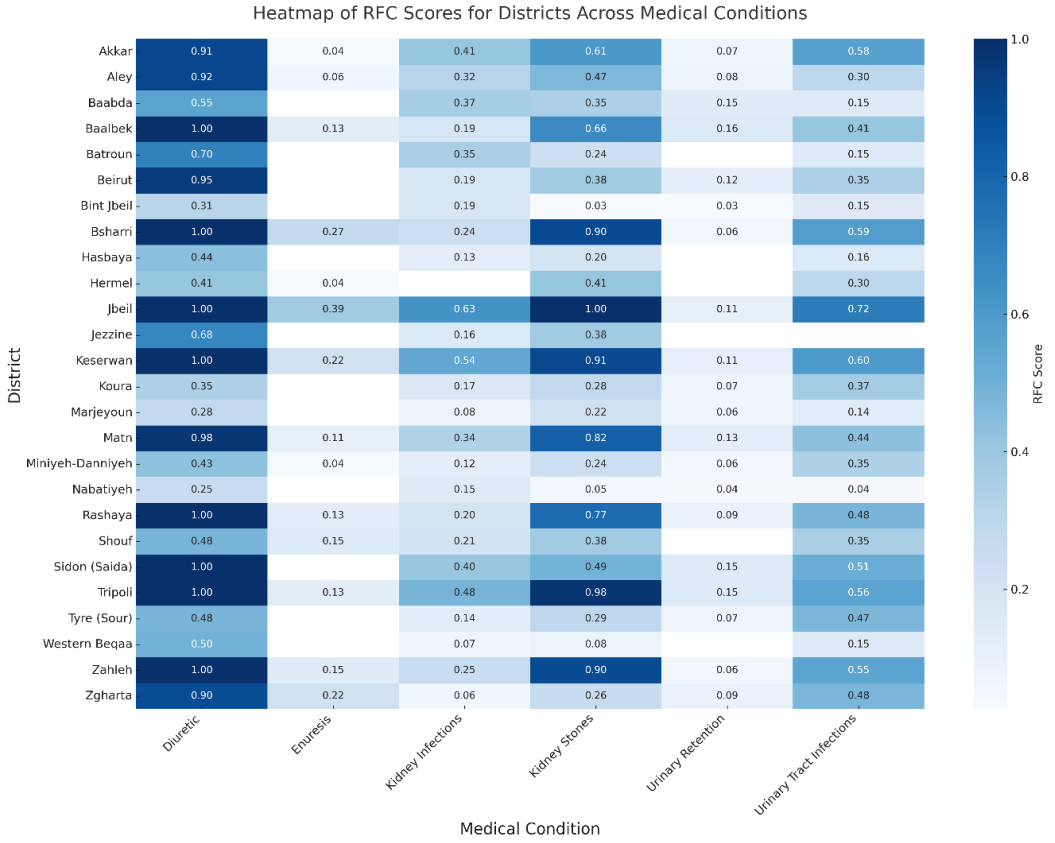

Figure 4. Heatmap of Relative Frequency of Citation (RFC) Scores by Districts for Kidney and Urinary Disorders in Lebanon.

partner regions demonstrate higher adoption rates than morphologically or chemically divergent species. This is in line with results reported by Leonti and Casu (2013), who showed that traditional pharmacopoeias in the Mediterranean region are historically dynamic systems shaped by long-standing processes of intercultural exchange and the continuous incorporation of external botanical knowledge. For instance, Lebanon's historical position along ancient trade routes—particularly the Silk Road networks that connected European, Asian, and African medicinal traditions—facilitated extensive botanical knowledge exchange that is now embedded within contemporary traditional practices. This aligns with broader historical patterns, where transregional exchange networks introduced hundreds of medicinal plants across continents, enriching local pharmacopoeias through long-term intercultural contact and integration (Shan et al. 2024). The successful integration of imported species challenges essentialist notions of "traditional" medicine as static or locally bounded, instead revealing traditional knowledge systems as dynamic, globally connected networks capable of evaluating, testing, and incorporating innovations when they demonstrate superior therapeutic efficacy or practical advantages over existing remedies. This adaptability represents a critical characteristic of resilient medical systems, enabling them to maintain therapeutic effectiveness despite environmental, economic, or social disruptions that might limit access to previously preferred species.

Conversely, the limited utilization of endemic (RFC = 0.09-0.15) and naturalized (RFC = 0.032) plant species provides important insights into the constraints operating within traditional knowledge systems. While previous ethnobotanical studies have documented the taxonomic presence of endemic species in traditional pharmacopoeias (Cocco et al. 2022), few have quantified their actual usage frequency relative to other plant categories. Our RFC analysis provides novel quantitative evidence for what the Ecological Apparency Hypothesis theoretically predicts: that apparent, easily accessible plants are preferentially selected over rare or geographically restricted species. The endemic species paradox observed here—whereby locally unique plants receive minimal therapeutic attention despite their potential pharmacological novelty—demonstrates that traditional plant selection operates through structured cultural processes rather than simple botanical availability. Endemic species, by definition, have restricted distributions that may

limit practitioners' opportunities for empirical evaluation and knowledge transmission (Hermant et al. 2013). Similarly, the marginalization of naturalized species suggests that successful integration into traditional pharmacopoeias requires extended periods of cultural evaluation and knowledge transmission that recent colonizers have not yet achieved. These RFC-based patterns provide the first quantitative demonstration that traditional medicine systems prioritize proven efficacy and reliable availability over botanical novelty or ecological uniqueness.

These plant origin patterns collectively reveal the operation of what we propose as "biocultural selection pressures"—evolutionary-like forces that shape traditional pharmacopoeias through the interaction of ecological availability, cultural transmission mechanisms, therapeutic efficacy assessment, and social reproduction of medical knowledge. The highly significant statistical associations observed ($\chi^2 = 244.10$, $p = 1.77e-40$) demonstrate that these patterns represent structured, non-random processes reflecting deep biocultural adaptations rather than opportunistic resource utilization. From a conservation perspective, these findings suggest that indigenous and cultivated medicinal plants may benefit from enhanced cultural protection due to their embedded significance within traditional knowledge systems, while endemic species face potential "orphan taxa" status that could compromise both cultural preservation and biodiversity conservation objectives. Understanding these biocultural dynamics provides essential insights for developing culturally appropriate conservation strategies that simultaneously preserve botanical diversity, maintain traditional knowledge systems, and support community health practices within Lebanon's rapidly changing socioeconomic landscape.

Associations between Preparation Methods and Medical Conditions

The analysis of preparation methods versus medical conditions in traditional Lebanese medicine revealed structured patterns indicating specific associations between preparation methods and ailments (Additional File 1). Preparation methods, such as Decoction (DEC) and Infusion (INF), emerged as the most frequently cited, particularly for DIU and UTI, with RFC scores of 1.0 for both conditions (Figure 6). This high RFC suggests that these methods hold a prominent place in traditional practices, likely due to their effectiveness and accessibility, making them trusted choices within the community for treating common kidney and urinary conditions. In Lebanon, decoction has been identified as the most commonly used preparation method, followed by infusion, while less frequently employed methods include maceration and the use of latex or fresh juice (Hani et al. 2022). Decoction and infusion are particularly prevalent in the treatment of urinary tract diseases, including kidney stones, urinary tract infections, renal failure, and enuresis (Jaradat et al. 2017). Decoction is favored for its ability to break down plant tissues through heat, thereby facilitating the release of bioactive compounds into water. However, the short shelf life of decoctions necessitates frequent preparation, which may increase pressure on the availability of medicinal plants and underscores the importance of sustainable harvesting practices (Jaradat et al. 2016; Hani et al. 2022). These observations align with global trends, where decoction is frequently noted as the primary preparation method for kidney disorders. For instance, in North-Eastern Morocco, decoction is similarly the predominant method, followed by infusion, while alternatives such as powder, maceration, and juice are less commonly used (Bencheikh et al. 2021). The widespread adoption of decoction can be attributed to its efficacy in extracting curative constituents, neutralizing toxins, and warming the body, making it a reliable method in traditional medicine (Halberstein 2012; Tahri et al. 2012). In Morocco, decoctions of aerial parts from Herniaria hirsuta are used to treat kidney stones, while decoctions of A. graveolens are employed to alleviate kidney swelling. Infusions of leaves, on the other hand, are commonly used to address pyelonephritis and renal colic, further highlighting the adaptability of these preparation methods to specific medical conditions (Bencheikh et al. 2021).

Conversely, methods such as Juice (JUI) and Fumigation (FUM) showed significantly lower citation frequencies, with RFC values such as 0.029 for ENU, suggesting they are reserved for more specialized or culturally specific applications (Figure 6). The Chi-Square Test of Independence yielded a highly significant result ($\chi^2\ (55, N = 310) = 449.18$, $p = 3.23e-63$), confirming that the use of specific preparation methods is non-random and instead strongly associated with particular medical conditions. These findings underscore that certain preparation methods, like DEC and INF, are culturally embedded in traditional healthcare due to their perceived efficacy, ease of preparation, and longstanding use. The moderate RFC scores observed for methods such as Fresh Use (FUS) and Maceration (MAC) indicate their valued yet more limited applications, likely chosen for conditions or contexts where simpler methods are preferred. On the other hand, the low RFCs for methods like Fumigation (FUM) suggest niche practices that may align with specific therapeutic needs. In traditional Lebanese medicine, the use of JUI and MAC is infrequent, accounting for a modest portion of preparation methods, with each representing a small percentage of overall usage (Hani et al. 2022). Similar

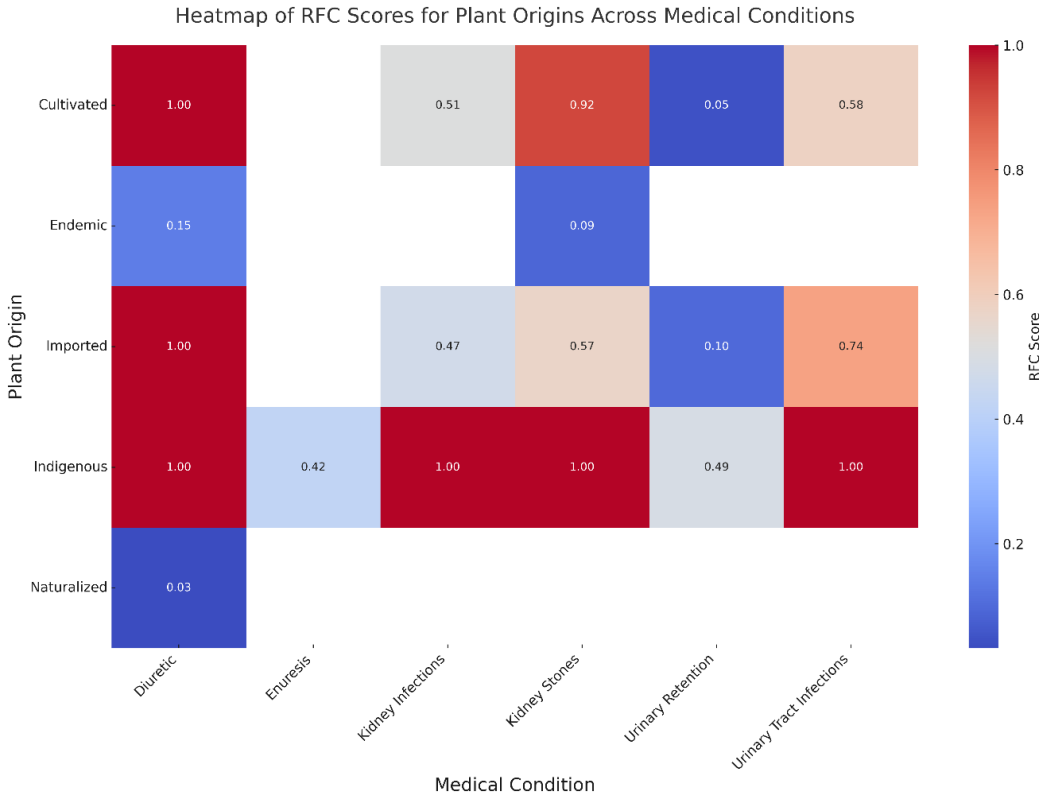

Figure 5. Heatmap of RFC Scores for Different Plant Origins in the Treatment of Kidney and Urinary Disorders Across Medical Conditions.

trends have been documented in Morocco, where these practices constitute only 6% of preparation methods, highlighting their targeted application in specific therapeutic contexts (Bencheikh et al. 2021). In contrast, the use of FUM for kidney and urinary disorders is culturally specific and notably less prevalent than other preparation methods. This limited usage may stem from the niche applications of fumigation, which are often associated with rituals or practices aimed at holistic healing rather than the direct treatment of physical symptoms. Research into the efficacy of fumigation for kidney and urinary disorders is sparse, with its use primarily rooted in ethnomedicinal traditions rather than supported by robust clinical evidence. Further investigation is needed to substantiate its therapeutic value and clarify its role within traditional healthcare systems. This pattern reflects a nuanced cultural rationale for preparation choices, with factors such as perceived potency, historical anecdotes, and preparation convenience playing roles in these selections.

CONCLUSION

This study provides a comprehensive analysis of the ethnopharmacological practices in Lebanon, focusing on the traditional use of plants for treating kidney and urinary disorders. By systematically documenting plant parts, origins, preparation methods, and regional preferences across 26 districts, this research highlights the structured and culturally embedded nature of Lebanese traditional medicine. The significant findings indicate not only the cultural prominence of certain plant species, such as those from the Asteraceae and Apiaceae families, but also the nuanced application of specific preparation methods—particularly decoction and infusion—for commonly encountered renal conditions. Importantly, the identification of the most culturally significant species was quantitatively supported by the use of ethnobotanical indices, including RFC, UV, and RI. These metrics provided a robust analytical framework for assessing the prominence and therapeutic relevance of specific plants within community health practices, reinforcing the evidence-based structure underlying traditional knowledge. This study emphasizes that these practices are neither arbitrary nor purely anecdotal; they reflect a deep-rooted body of knowledge that has evolved through generations to address the healthcare needs of the community effectively. The reliance on indigenous and cultivated plants underscores the value placed on accessible and locally abundant resources, which may contribute to the sustainability and resilience of

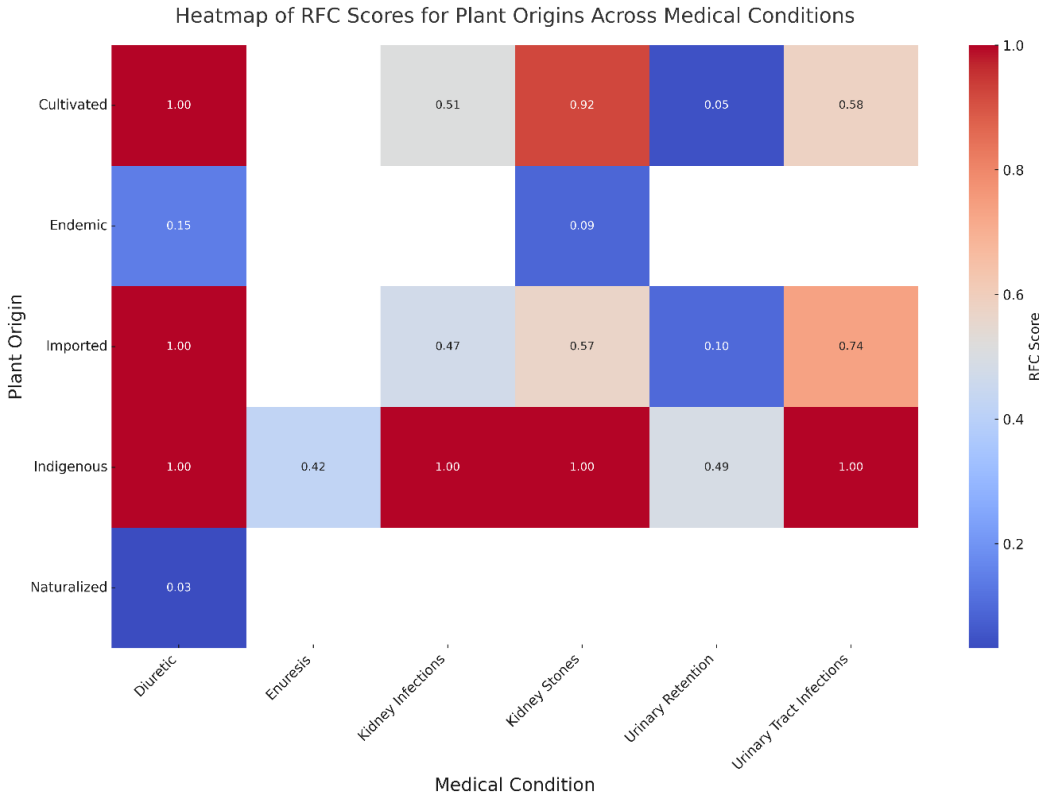

Figure 6. Heatmap of RFC Scores for Preparation Methods Used in Treating Kidney and Urinary Disorders Across Medical Conditions.

these practices within the Lebanese healthcare context. Moreover, by systematically documenting traditional practices, this study preserves oral knowledge that is at risk of erosion due to modernization and social change. The identification of culturally important species provides a focused basis for conservation strategies aimed at protecting the botanical resources essential to traditional healthcare systems. In parallel, by offering a structured scientific platform grounded in ethnobotanical indices, this research facilitates future pharmacological investigations, potentially validating and integrating traditional remedies into contemporary medical frameworks. Additionally, the empirical evidence generated in this study can inform public health policies and awareness campaigns, holding greater institutional recognition and support for traditional knowledge. While broader societal and policy-level interventions remain necessary, this study contributes a critical scientific foundation that enhances the resilience and continued relevance of Lebanon's ethnomedical heritage.

As global interest in ethnopharmacology grows, this research advocates for the preservation of Lebanon's rich botanical heritage and underscores the importance of culturally adaptive healthcare solutions. Protecting this knowledge is crucial, not only for conserving biodiversity but also for supporting alternative healthcare strategies that align with the lived experiences and needs of local populations. Future research should build on these findings by investigating the biochemical properties and therapeutic mechanisms of these plants, fostering a holistic approach that bridges traditional wisdom and modern scientific inquiry. In doing so, this study paves the way for sustainable, evidence-based applications of traditional medicine in treating kidney and urinary disorders.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: MB, CAK Carried out the experiment: MB, CAK, CS
Carried out the data analysis: MB, CAK, ST, MAK, JBS, CS, LAS, AS, SF, CK
Wrote the first draft of the manuscript: MAK, JBS, CS, LAS, AS, SF, CK.
Review and final write of the manuscript: CAK, ST.
Supervision: CAK.

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