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Review Article

Medicinal Plants of Sudan: Diversity, Ethnobotany, Phytochemistry, and Pharmacological Potential — A Review

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Abstract

Sudan is endowed with a rich and underexplored diversity of medicinal plants that have been used for centuries in traditional medicine. This review consolidates current knowledge about the diversity, distribution, ethnobotanical uses, phytochemistry, pharmacological evidence, toxicity, conservation status, and research gaps of Sudanese medicinal plants. We conducted a systematic literature search using databases such as PubMed, PMC, ScienceDirect, and Google Scholar, focusing on keywords including "Sudan medicinal plants", "ethnobotany Sudan", "phytochemistry Sudan", and "pharmacology Sudan". We document over 300 medicinal species across various ecological zones, highlight key taxa such as Acacia senegal, Balanites aegyptiaca, Hibiscus sabdariffa, Adansonia digitata, and Senna spp. Traditional applications include treatment of infections, gastrointestinal disorders, malaria, diabetes, liver diseases, wounds, hypertension, and inflammatory conditions. Phytochemical investigations reveal the presence of flavonoids, tannins, phenolics, saponins, alkaloids, glycosides, and terpenoids. Experimental studies (*in vitro* and *in vivo*) often support traditional uses, but clinical trials remain limited. Toxicological studies are sparse, indicating the need for thorough safety evaluation. Conservation concerns arise due to habitat loss and overharvesting. We propose directions for future research including rigorous clinical trials, quality control, sustainable cultivation, and integration into formal healthcare.

Keywords: Medicinal Plants; Sudan; Ethnobotany; Phytochemistry; Pharmacology; Traditional Medicine; Conservation

Introduction

Traditional medicine remains an important component of healthcare in many developing countries, including Sudan, where herbal remedies are commonly used, particularly in rural and remote communities. In an Omdurman cross-sectional study, 85.9% of adult respondents reported using herbal medicine, with peppermint, Acacia nilotica, Hibiscus sabdariffa, ginger, and fenugreek among the commonly reported remedies [2,6,15]. This level of use emphasizes the continuing cultural and practical importance of medicinal plants and the need to evaluate traditional knowledge alongside scientific evidence.

Sudan possesses considerable botanical diversity, with approximately 3,137 species of flowering plants distributed among 170 families and 1,280 genera, with about 15% reported as endemic [7,11]. The country encompasses contrasting ecological zones, including desert and semi-desert environments, Sahelian and Sudanian savannahs, and Nile riparian habitats. These environments provide diverse plant resources and contribute to

substantial regional variation in medicinal-plant availability and traditional use.

The scientific literature on Sudanese medicinal plants is, however, dispersed across ethnobotanical, phytochemical, pharmacological, toxicological, and conservation studies. Although many reports describe promising biological activities, the strength of evidence is uneven, and laboratory findings cannot automatically be considered evidence of clinical efficacy. Important gaps remain in standardized preparation, dose definition, toxicity assessment, clinical validation, conservation, and documentation of traditional knowledge.

The purpose of this review is therefore to consolidate available information on the diversity and geographic distribution of Sudanese medicinal plants; summarize ethnobotanical uses and traditional preparation practices; examine major phytochemical groups and reported pharmacological activities; consider toxicity, conservation, economic and socio-cultural dimensions; and identify research priorities required for scientifically supported and sustainable integration into formal healthcare [11,21,35].

Methods

A structured literature review was undertaken using PubMed, PMC, ScienceDirect, Google Scholar, and regional journals. Search terms and combinations included "Sudan medicinal plants", "ethnobotany Sudan", "phytochemistry Sudan", "pharmacology Sudan", and "traditional medicine Sudan". Eligible sources included peer-reviewed original articles, review articles, ethnobotanical surveys, and pharmacological or phytochemical studies specifically addressing medicinal plants occurring in Sudan. Non-English publications were excluded unless an English abstract was available, and studies not involving Sudanese flora were excluded. Information was extracted and organized by scientific name, family, vernacular name(s), geographic distribution, plant parts used, traditional indications, preparation and administration, phytochemical constituents, pharmacological activity, toxicity information, and conservation status. Evidence was synthesized descriptively rather than by meta-analysis because the identified studies differed substantially in plant material, extract preparation, experimental models, endpoints, and reporting. Representative species and selected pharmacological studies were summarized in tables to facilitate comparison. The review also considered the limitations of the available evidence, particularly the predominance of preclinical studies and the limited availability of clinical and toxicological data.

Diversity and geographic distribution of medicinal plants in Sudan

Taxonomic diversity

A number of reviews and surveys highlight Sudan's medicinal plant diversity. The review Medicinal and Aromatic Plants from Sudan provides an overview of dozens of species, habitats, traditional uses, and phytochemistry. Another significant body of literature catalogues numerous medicinal taxa and aligns pharmacological data with folklore uses [1,7,11,21].

A recent ethnobotanical survey in the Melit area of North Darfur recorded 59 medicinal plants belonging to 32 families and 55 genera, with 45 medicinal uses documented. The study also highlighted the importance of documenting traditional knowledge before it is lost [41].

Geographic and ecological distribution

Sudan's ecological zones—desert, semi-desert, Sahelian, Sudanian savannah, and Nile riparian zones—support different floristic assemblages. Medicinal plants cluster in riverine zones, seasonal-flood plains, savannah woodlands, and marginal semi-arid areas. Some species are generalists (e.g. Acacia spp.), while others occupy more specialized niches (e.g. riparian species, floodplain shrubs). The EOLSS sample chapter lists ~33 species with special cultural position in Sudan, including Acacia nilotica, Acacia senegal, Adansonia digitata, Aerva javanica, among others [7,11,18]. Distribution maps at state level are scarce in literature; but many regional ethnobotanical studies (Darfur, Kordofan, Gadarif, Blue Nile, etc.) provide localized species lists [12,17,18].

Ethnobotanical uses and traditional practices

Usage prevalence and cultural patterns

Herbal medicine use is deeply embedded in Sudanese culture. In a cross-sectional study in Omdurman, 85.9% of participants reported using herbal remedies; the most used herbs were peppermint (73.8%), Acacia nilotica (71.4%), hibiscus (79.9%), ginger (69.8%), and fenugreek (66.9%) [2,6].

Plants are used in multiple disease categories: infections, gastrointestinal disorders, malaria, diabetes, liver disorders,

wound healing, respiratory ailments, hypertension, and more [1,6,12,21].

Preparation methods and modes of administration

Common preparation modes include decoction, infusion, maceration, poultice, paste, powder, smoke, and direct use. In traditional medicine reports, decoction and infusion are frequently mentioned, but powder, paste, poultice, smoke, and mucilage are also used [6,21,36].

Administration routes are predominantly oral, but also topical (for wounds) and occasionally nasal or rectal [6,36].

Some unique traditional practices exist; e.g., "dukhan" (smoking the body) is used in northern Sudan for rheumatic pain, postpartum care, or even treatment of syphilis/gonorrhea in traditional contexts [36].

Disease categories and examples of use

Table 1 summarizes representative medicinal species, their traditional uses, parts used, and modes of preparation [6,13,14,15,29].

Scientific name	Family	Part(s) used	Traditional uses/diseases treated	Preparation/administration
Acacia senegal	Fabaceae	Gum, bark, leaves	Demulcent, wound dressing, anti-ulcer, diarrhea	Decoction, paste, oral
Balanites aegyptiaca	Balanitaceae	Fruit pulp, bark, seeds	Antidiabetic, anthelminthic, hepatic disorders	Decoction, powder, oral
Hibiscus sabdariffa	Malvaceae	Calyces, leaves	Hypertension, diuretic, digestive aid	Infusion, decoction, juice
Adansonia digitata	Malvaceae	Fruit pulp, leaves	Diarrhea, malnutrition, liver support	Decoction, pulp in water, oral
Senna spp.	Fabaceae	Leaves, pods	Laxative, constipation, digestive complaints	Decoction, infusion, oral

Table 1: Representative Sudanese Medicinal Plants and Traditional Uses.

More local surveys (e.g. Melit, Darfur) report species such as Carica papaya, Corchorus trilocularis, Heliotropium sudanicum, Solanum forskalii, and Tephrosia purpurea, used for swellings, respiratory, and gastrointestinal disorders [18]. Ethnoveterinary uses of medicinal plants are also documented in Sudan and provide an additional context for the therapeutic use of these plants [30]. Guiera senegalensis has also been reported in traditional medicinal practice in Western Kordofan [39].

Phytochemistry and bioactive compounds

Primary screening and phytochemical profiles

Qualitative phytochemical screening of many Sudanese medicinal plants reveals the presence of flavonoids, tannins, phenolics, saponins, alkaloids, glycosides, terpenoids, and steroids. Phytochemical screening and antibacterial studies of selected Sudanese medicinal plants support the occurrence of these constituent classes [8,25].

Analytical studies, including GC-MS and related profiling approaches, provide more precise molecule-level understanding of compounds in Sudanese plant extracts. The GC-MS analysis of Balanites aegyptiaca fruit volatile oils provides an example of this approach [23].

In Medicinal and Aromatic Plants from Sudan, the authors summarized known phytochemical constituents for dozens of species [1,7].

Selected phytochemicals and their activities

Flavonoids and phenolics are common antioxidant, anti-inflammatory, and antimicrobial agents. Tannins are often associated with astringent and antimicrobial properties. Saponins and glycosides may contribute to hypoglycemic and cytotoxic effects. Alkaloids often have potent pharmacological actions and require toxicity evaluation. Terpenoids have diverse effects

including anti-inflammatory, cytotoxic, and antimicrobial activities [8,25,38].

Example: Boscia salicifolia (found in Sudan/Sahel) contains flavonoid glycosides such as rhamnetin 3-O-β-neohesperidoside and rhamnocitrin 3-O-β-glucopyranoside [Source verification required].

Also, Boscia angustifolia has been reported to contain compounds including ombuin and other constituents, with antioxidant and antiviral activities reported in some studies [Source verification required].

Pharmacological and toxicological evidence

Antiprotozoal and antimalarial studies

In a survey titled Mining Sudanese Medicinal Plants for Antiprotozoal Agents, plant extracts from Sudan were screened against Plasmodium falciparum and trypanosomatid parasites. The work emphasizes the untapped potential of Sudanese flora for antimalarial and anti-NTD drug leads [3]. Antiplasmodial activity of some Sudanese medicinal plants has also been reported experimentally [20].

Antifungal and antimicrobial activities

A review of Sudanese medicinal plants screened for antifungal action documented 85 species in 48 families; Acacia nilotica was among the most frequently tested. Methods such as cup-plate diffusion were common [4].

Other microbial assays (bacterial and fungal) are routinely included in phytochemical studies of Sudanese plants [8,14,22,23,26,29].

The study by Nabaa., *et al*. showed that Guiera senegalensis leaf extract in Sudan had no inhibition activity against all of the tested fungal strains. On the other hand, the toxicity test, which was conducted using brine shrimp, suggested that G. senegalensis leaf extract was apparently not toxic [40].

Antidiabetic and hypolipidemic effects

The review Exploring Sudanese Medicinal Plants for their Antidiabetic and Hypolipidemic Benefits reviews multiple species showing hypoglycemic and lipid-modulating effects in experimental models; mechanisms often involve upregulation of insulin, inhibition of gluconeogenesis, and antioxidant protection [24].

Other Sudanese plants have also been screened for antidiabetic activity using *in vitro* and *in vivo* assays [24,25].

Other pharmacological effects

- **Hepatoprotective/liver support:** Some Sudanese plants have shown protective effects in liver injury models, including Adansonia digitata fruit and leaf extracts [13].
- **Anti-inflammatory and analgesic:** Traditional claims for pain and rheumatic conditions are sometimes supported in experimental models. Acacia nilotica and Acacia seyal bark extracts have also been investigated for antimicrobial and anti-inflammatory properties [22].
- **Antioxidant/cytotoxic/anticancer:** Preliminary screening in some extracts shows cytotoxicity toward cancer cell lines and antioxidant activity [9,19,27].
- **Cardiovascular/antihypertensive:** Hibiscus sabdariffa in Sudan has traditional use for hypertension; pharmacognostic, phytochemical, and antioxidant studies have investigated this plant [16,27].
- **Toxicology/safety:** Few plants have been rigorously tested for toxicity. Reviews of medicinal plant toxicity emphasize that medicinal plants are not entirely free of side effects or toxicity [5]. Possible mutagenicity, carcinogenicity, or organ toxicity requires assessment [5,10].

Conservation, economic and socio-cultural aspects

Economic role and domestication

Gum arabic (from Acacia senegal) is a commercially valuable export product of Sudan, linking medicinal and industrial uses. Some medicinal plants are also used as food, fodder, timber, or multipurpose resources. Domestication and cultivation of medicinal species can reduce pressure on wild populations and may contribute to sustainable trade and rural development [31].

The potential economic value of Sudanese medicinal plants supports further work on sustainable utilization and value chains [31].

Conservation and challenges

Habitat loss, overharvesting, deforestation, agricultural expansion, and climate change threaten wild medicinal plant populations. Lack of propagation/cultivation protocols and inadequate legal protection exacerbate risks [32,37].

Ethnobotanical surveys warn that traditional knowledge is at risk of loss, especially as it is transmitted orally between generations. The Melit study emphasized documentation and preservation of this knowledge [41].

Integration with modern healthcare

Integrative use of validated medicinal plants in primary healthcare requires standardization, safety evaluation, regulatory frameworks, and quality control [10,33,34].

Community acceptance is already high (85.9% usage in one urban district) [2]. A thoughtful integration could reduce costs, increase access, and harness biodiversity sustainably [34,35].

Plant/group	Evidence area	Study context	Main reported finding	Evidence limitation
Acacia nilotica/ Acacia seyal	Antimicrobial and anti-inflammatory	Experimental extract studies	Reported antimicrobial and anti-inflammatory activities	Preclinical evidence; extract composition and doses vary [22]
Balanites aegyptiaca	Antimicrobial/phytochemical	Extract and GC-MS studies	Bioactive constituents and antimicrobial activity reported	Requires standardized extracts and further validation [14,23]
Hibiscus sabdariffa	Antioxidant/antihypertensive	Phytochemical and pharmacognostic studies	Antioxidant activity and traditional use for hypertension documented	Clinical evidence specific to Sudanese preparations remains limited [15,27]
Adansonia digitata	Hepatoprotective/nephroprotective	*In vivo* extract studies	Protective effects reported in experimental models	Animal findings require human confirmation [13,28]
Guiera senegalensis	Antifungal/toxicity	Leaf-extract laboratory studies	No inhibition against tested fungal strains; brine-shrimp test suggested low apparent toxicity	Limited strain/model coverage; safety evidence remains preliminary [40]
Sudanese medicinal plants (multiple taxa)	Antiprotozoal/antimalarial	*In vitro* screening	Several extracts showed potential against Plasmodium and trypanosomatids	Screening results do not establish clinical efficacy [3,20]

Table 2: Representative pharmacological and safety evidence for selected Sudanese medicinal plants.

The evidence assembled in this review indicates that Sudanese medicinal plants constitute a diverse resource in which traditional knowledge, phytochemical diversity, and experimental pharmacology frequently intersect. Ethnobotanical reports document broad use for infections, gastrointestinal disorders, malaria, diabetes, liver disorders, wounds, respiratory complaints, hypertension, and inflammatory conditions [1,6,12,21]. Experimental studies provide biological support for some of these traditional applications, including antimicrobial, antiplasmodial, antioxidant, antidiabetic, anti-inflammatory, and hepatoprotective effects [3,13,20,22,24,25,27]. Nevertheless, the relationship between traditional use and experimental activity should be interpreted cautiously. An *in vitro* or animal finding demonstrates biological potential, but it does not establish therapeutic effectiveness in humans.

A major strength of the available literature is its breadth across several disciplines. Ethnobotanical surveys help identify culturally important species and preparations, while phytochemical studies provide hypotheses for possible mechanisms of action. GC-MS and other analytical approaches can further characterize complex extracts and identify candidate compounds [23]. However, studies frequently differ in plant part, geographic origin, extraction solvent, concentration, assay system, and experimental endpoint. Such differences make direct comparison difficult and highlight the importance of authenticated plant material, standardized extraction procedures, chemical profiling, and reproducible bioassays.

The clinical and safety evidence remains the principal limitation. The reviewed literature contains substantially more preclinical than clinical evidence, while rigorous toxicological studies and herb–drug interaction data are limited [5,10,33]. This is particularly important because the presence of pharmacologically active constituents may also produce adverse effects at particular doses or in susceptible individuals. Future investigations should therefore evaluate acute, subacute, and chronic toxicity where appropriate, establish therapeutic windows, and assess interactions with conventional medicines before wider clinical adoption.

Opportunities lie in focusing on high-potential taxa (e.g. those with strong preliminary data), leveraging modern analytical methods (LC-MS, metabolomics), and collaborating across botanical, pharmacological, ethnomedical, regulatory, and cultivation domains [11,25,35,38].

The conservation dimension is equally important. Habitat loss, overharvesting, deforestation, agricultural expansion, and climate change may reduce populations of medicinal species, while the oral transmission of traditional knowledge creates a risk of losing information when communities are disrupted [32,37,41]. Sustainable cultivation, propagation protocols, community-based conservation, and documentation of traditional knowledge should therefore proceed alongside pharmacological development. Economically important species such as Acacia senegal also demonstrate how medicinal, food, fodder, and industrial uses can intersect with rural livelihoods and sustainable value chains [31].

Taken together, the evidence supports a research strategy that prioritizes well-documented, high-potential species while maintaining a clear distinction between traditional claims, laboratory evidence, animal evidence, and clinical evidence. Collaborative work involving botanists, ethnobotanists, pharmacologists, toxicologists, clinicians, analytical chemists, conservation specialists, and regulatory authorities would improve the quality and translational value of future research [11,25,35,38].

Conclusion and Future Directions

Progress in these areas would help convert promising traditional knowledge and experimental findings into reproducible, safe, and scientifically validated applications while protecting Sudan's medicinal-plant biodiversity and associated cultural knowledge.

- Development of evidence-based regulatory and policy frameworks for appropriate integration of validated medicinal products into healthcare.
- Research on conservation, climate resilience, community participation, and sustainable value chains.
- Geographic and genetic mapping of important medicinal species, together with propagation, domestication, and sustainable harvesting strategies.
- Integrated ethnobotanical documentation that preserves traditional knowledge while distinguishing traditional claims from experimentally demonstrated effects.
- Standardization of plant identification, harvesting, extraction, phytochemical profiling, and quality control.
- Systematic toxicological evaluation, including relevant organ toxicity and herb–drug interaction studies.
- Well-designed clinical studies to determine efficacy, appropriate dosage, and safety of selected preparations.

Future research should prioritize the following areas

Sudanese medicinal plants represent a substantial biological and cultural resource with documented diversity, extensive traditional use, and a growing body of phytochemical and pharmacological research. The evidence reviewed here shows that many species have promising antimicrobial, antiprotozoal, antidiabetic, antioxidant, anti-inflammatory, hepatoprotective, and other activities. However, the evidence base is heterogeneous and remains dominated by ethnobotanical observations and preclinical studies. Consequently, traditional use and laboratory activity should be regarded as a basis for further investigation rather than as proof of clinical efficacy.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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