Herbal Drugs from Sudan: Traditional Uses and Phytoconstituents
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ABSTRACT
Sudan folklore medicine is characterized by a unique combination of Islamic, Arabic, and African cultures. In poor communities, traditional medicine has remained as the most reasonable source of treatment of several diseases and microbial infections. Although the traditional medicine is accepted in Sudan, to date there is no updated review available, which focuses on most effective and frequently used Sudanese medicinal plants. Thus, this review aims to summarize the published information on the ethnomedical uses of medicinal plants from Sudan, preparation methods, phytochemistry, and ethnopharmacology. The collected data demonstrate that Sudanese medicinal plants have been reported to possess a wide range of traditional medicinal uses including different microbial infections, gastrointestinal disorders, malaria, diabetes, rheumatic pain, respiratory system disorders, jaundice, urinary system inflammations, wounds, cancer, and different microbial infections. In most cases, the pharmacological studies were in agreement with traditional uses. Moreover, several bioactive compounds such as flavonoids, saponins, alkaloids, steroids, terpenes, tannins, fatty acids, and essential oils have been identified as active constituents. Although this review demonstrates the importance of ethnomedicines in the treatment of several diseases in Sudan, further researches to validate the therapeutic uses and safety of these plants through phytochemical screening, different biological activity assays, and toxicological studies are still needed.

Key words: Antimicrobial agents, biological activity, medicinal plants, phytoconstituents, Sudan, traditional medicine

INTRODUCTION
Traditional medicine has been used for the treatment of human illnesses since long time and is mainly based on components derived from natural products, from herbs, plants, and animals. Medicinal natural products are very frequently used in Sudan and also are widely consumed in Africa and all over the world. About 80% of the populations in African countries depend on traditional medicine for their primary health care.[1] In Sudan, 90% of Sudanese population depends mainly on traditional medicine since admission to hospitals and obtaining modern synthetic drugs are limited and a high percentage of the population is nomads.[2,3] Sustainability of the use of medicinal plants is an important concern. The demand for medicinal plants is increasing in Africa as the population grows and pressure on medicinal plant resources will become greater than ever. Interest in plant-derived medicines has also increased in the developed countries among the pharmaceutical companies.[4] In contrast, due to their minor side effects, the medicinal plants are widely used to treat many human diseases.[5] The increasing cost of health care and the failure of allopathic medicine to treat some diseases have also participated to the increasing consumption of traditional medicine to fight disease. Until now, there is no pharmacopoeia or formal training for the traditional medical healers in Sudan, and their knowledge is completely based on acquired folklore and local traditions. Medicinal plants with a long history of safe and efficient use are likely to have a pharmaceutical outcome.[6] However, almost all of the medicinal herbal products are unlicensed and are not required to demonstrate efficacy, safety, or quality. Unknown consequences of some of medicinal plants have been detected. Examples of toxic reactions, allergic reactions, drug interactions, drug contamination, and mistaken plant identities are provided.[7] This review describes the traditional uses of 48 medicinal plants from Sudan. These plants are distributed into 26 families. The most common families are Fabaceae (12 species) followed by Combretaceae (4 species), Capparidaceae and Capparaceae (3 species each), Meliaceae, Asclepiadaceae, Anacardiaceae, and Malvaceae (2 species each), and other families are represented with one species each [Table 1]. Different plant parts including leaf, stem, root, fruit, seed and bark, aerial part, and whole plant are used in the preparation of medicines. There is a distinct preference for leaf (25%), fruit (23%), and stem (17%) materials [Figure 1]. Drugs were prepared mostly through decoction (19 species) and maceration (13 species). However, other techniques such as infusion (8 species), poultice and smoke (7 species each), powder and paste (6 species each), directly (2 species), and mucilaginous and desert (1 species each) are also employed [Figure 2]. Prepared remedies are administered or prescribed in several ways including orally, nasally, or anally. The majority of the species are extensively used in traditional medicine against infections, inflammation, diabetes, bleeding, malaria,
diarrhea, and digestive disorders. A summary of the most important Sudanese medicinal plants, their botanical families, local names, and traditional usage is presented in Table 1.

The Convention on Biological Diversity (CBD) was opened for signature in 1992 and entered into force in December 1993. It was signed by Sudan in June 1992 and ratified in October 1995, addressing at global level the entire spectrum of biological diversity, the sustainable use thereof and the fair and equitable sharing of the benefits accruing from that use.[71] All plants mentioned in this study are native to Sudan. In this review, we have considered the medicinal plants from the whole Sudan as one single country; however, in July 2011, Sudan was split into two countries (Sudan and South Sudan). The main question now: How will the medicinal plants and forests of the previous United Sudan be divided between the two new countries and which of the two new countries will benefit from legal protection as laid out by CBD?

OVERLAP BETWEEN FOOD AND MEDICINE IN SUDAN

Overlap between food and medicine is a common phenomenon in Sudan. Many plant substances are used as both foods and medicines. For example, the plants Capsicum frutescens, Ziziphus spina-christi, Cymbopogon proximus, Grewia tenax, Hyphaene thebaica, Hibiscus sabdariffa, Trigonella foenum-graecum, Tamarindus indica, and Sesamum indicum are not only known herbal medicines but also foods, drink, and/or flavorings.[8-11,23,42,52,53,55,59-63,72,73] Moreover, in Sudan and many other countries, foods containing biologically active natural constituents are eaten regularly. For instance, luteolin is a known biologically active flavonoid found in celery, green pepper, thyme, chamomile tea, perilla, carrots, peppermint, olive oil, rosemary, navel oranges, oregano, and other foods.[74,75]

PHYTOCHEMISTRY AND PHARMACOLOGICAL PROPERTIES

The traditional medicinal applications of Sudanese plants have encouraged many pharmacological investigations. Several extracts and purified compounds have been assessed for their biological activities, especially antibacterial, antioxidant, antimalarial, antifungal, anti-inflammatory, anticancer, and antidiabetic activities [Figure 3]. There appears to be an interest in developing novel drugs for many diseases from these plants due to their different classes and high contents of phytoconstituents based on natural products as lead structures. The active components in herbal medicines are directly associated with their ability to treat or prevent ailments. Phenolics, alkaloids, tannins, flavonoids, saponins, and steroids are the most bioactive compounds identified in these plants. Table 2 lists some the available pharmacological studies, bioactive constituents, and assays based on folk knowledge of the most active and frequently used Sudanese medicinal plants.

ANTIMICROBIAL, PHYTOCONSTITUENTS, AND TRADITIONAL MEDICINAL USES OF SOME SELECTED SUDANESE PLANTS

Several pharmacological studies have demonstrated the antimicrobial activities of the medicinal plants, supporting its traditional uses. Phytochemical studies on these plants have demonstrated the occurrence of many classes of bioactive compounds, including flavonoids, terpenes, lignans, proanthocyanidines, and chlorogenic acids, among others [Table 2]. In the following section, selected medicinal plants are described in more details with respect to the traditional uses, phytoconstituents, and antimicrobial activities.

Azadirachta indica A. Juss. (Meliaceae)

Azadirachta indica is widely used in folkloric medicine for the treatment of variety of diseases in remote areas of Sudan. For instance, the decoction of leaves and roots is used for snake, scorpion bites and intestinal spasm, respectively.[8] The infusion of the leaves is used for treating malaria, fever, and jaundice [Table 1].[10] Furthermore, the powder of the dried leaves is mixed with water and taken to treat freckles and to increase appetite.[297,298] A. indica has also been scientifically proved for its antibacterial,[129] antiparasitic,[125] neuroprotective,[125] antimalarial,[186,126]
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Table 1: Sudanese medicinal plants, their local names, and traditional usage

| Plant name | Family | Local Sudanese names | Part used | Preparation | Traditional medicine uses | References |
|------------|--------|----------------------|-----------|-------------|---------------------------|------------|
| A. javanica (Burm. F.) Juss. Ex Schult. | Amaranthaceae | Umm Shara | Whole plant | Poultice | For swellings, wounds and as a potent | [8,9] |
| A. leiocarpos (DC.) Guill. and Perr. | Combretaceae | Sahab | Stem bark | Decoction | Against cough, dysentery, and giardiasis | [10] |
| A. senegal (L.) Willd. | Fabaceae | Al-Talih | Stem | Smoke, decoction | Against jaundice, rheumatic pain and as mouth deterrent | [8,11-14] |
| A. hispidum Schrank. | Asteraceae | Hourab | Aerial part | Decoction | Antimarial | [15,16] |
| A. senegalensis (Pars.) Lam. | Capparidaceae | Al-Garad | Fruits, stem | Powder | Against diabetes chronic renal failure, ulcers, and diarrhea | [11,17] |
| A. nilotica (L.) Willd. ex Del. | Fabaceae | Al-Gongelez | Paste, smoke | Antipyretic, malarial, hepatitis C virus, molluscicidal, colds, and pharyngitis | [10,18-22] |
| A. bracteolata Lam. | Aristolochiaceae | Um-Galagil | Fruits, roots | Maceration | Antimarial, tumor, scorpion bite, and HIV-1 | [15,16,23-25] |
| A. digitata L. | Bombacaceae | Al-Gongelez | Fruits | Decoction | Against diarrhea, malaria, cold, and amoebic dysentery | [10,26] |
| A. polycantha Willd. | Fabaceae | Abu-Sineina/ Kakamoat | Leaves, smoke, powder | Antimarial, headache, and against jaundice | [8,16,23] |
| A. sinkatana Rey. | Liliaceae | Al-Handal | Fruits, seeds, roots | Smoke, infusion, decoction | Against jaundice, rheumatic pain, dysentery, sexual debility, and schistosomiasis | [10,14] |
| A. amara (Roxb.) Boiv. | Fabaceae | Arrada | Leaves | Poultice, directly (seeds) | Against constipation, anthemlinitic, skin diseases, colon inflammation, fever, diabetic and hemorrhoids | [29,30] |
| A. indica A. Juss. | Meliaceae | Al-Neem | Leaves, roots, seeds, roots | Paste, decoction | Against jaundice, mouth inflammation, pain, and wounds | [9,14,30] |
| C. edulis (Frosk) Edgew. | Capparidaceae | Al-Tundub | Stem | Poultice, directly (seeds) | Antimarial, fever, jaundice, helminthisis, and skin diseases | [8,10,31,32] |
| C. occidentalis L. | Leguminosae | Al-Soreib | Leaves | Infusion, decoction | Antimarial and jaundice | [8,9,33] |
| G. villosa Willd. | Tiliaceae | Alikiko | Seeds, roots, stems | Decoction | Against cancer | [10] |
| C. quadrangularis L. | Vitaceae | Al-Salaaalaa | Leaves, seeds, roots | Maceration, poultice, smoke | Antimarial, bone fracture, acne, evil eye, and tuberculosis | [10,34] |
| C. colocythis (L.) Schrad. | Cucurbitaceae | Al-Handal | Fruits, seeds, roots | Smoke, poultice, directly (seeds) | Against eczema, diabets, constipation, swellings, and scabies | [9,35,36] |
| C. hartmannianum Schweinf. | Combretaceae | Al-Habiel | Bark, stem, leaves | Infusion | Antibacterial, jaundice, wounds, and fever | [8,27] |
| C. procura (Ait.) Ait. F. | Asclepiadaceae | Al-Ushar | Leaves | Infusion, paste | Against jaundice, scorpion bites, thorn injuries, rheumatic and as mouth deterrent | [9,11,14] |
| C. zambesicus Muell-Arg. | Euphorbiaceae | Habat | Seeds | Decoction | Antimicrobial, antimalarial, HIV-1 and cough | [15,24,35,37-40] |
| E. abyssinica L. | Fabaceae | Al-Malook | Bark, seeds | Decoction | Antimicrobial and jaundice and rheumatic pain | [10,41] |
| E. cretica L. | Zygophyllaceae | Umm-Shuwaika | Whole plant | Smoke, powder | Against heartburn, muscular pains, spasm and as purgative | [8,9,42] |
| L. pyrotechnica (Forsk.) DC. | Asclepiadaceae | Ajwam | Stem, root | Maceration, smoke | Antimicrobial, antimalarial, HIV-1 and cough | [9,11] |
| M. crassifolia Forsk. | Capparaceae | Sarah | Stem | Smoke | Antimicrobial and jaundice | [9] |
| M. angolensis DC. | Capparaceae | Shager-Elzaraf | Leaves | Maceration | Against breast tumor | [10] |
| S. persica L. | Salvadoraceae | Al-Miswak/ Arak | Stems, fruits, leaves | Paste, directly (stem) | Against breast tumor, scurvy, and mouth infection | [24,35,41,43-47] |
| S. alexandrina Mill. (C. senna L.) | Fabaceae | Sena-Maka | Fruits | Decoction | Against constipation and GIT disorders | [11,42,48-50] |
| K. africana (Lam.) Benth. | Bignoniaceae | Um-Shitour | Fruits, seeds | Smoke, paste | Against breast tumor, hypertension and diabetes | [10] |

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Table 1: Contd...

| Plant name | Family | Local Sudanese names | Part used | Preparation | Traditional medicine uses | References |
|------------|--------|----------------------|-----------|-------------|--------------------------|------------|
| C. glandulosa Forssk. | Capparaceae | Kurmut | Whole plant | Poultice | Against swelling and rheumatic pain | [8,9,14,42] |
| K. senegalensis (Desr.) A. Juss. | Meliaceae | Mahogany | Stem bark | Decoction, maceration | Antimalarial, diabetes, hepatic inflammation, sinusitis, skin diseases, stomach complaints, and trachoma | [10,11] |
| D. melanoxylon Guill. and Perr | Fabaceae | Al-Babanoose | Leaves | Infusion | Against heart pain and rheumatic pain | [8,14] |
| T. brownii Freyn. | Combretaceae | Al-Sobagh | Bark, stem | Maceration | Against cough, bronchitis, back pains, and rheumatic pain | [9,11,51] |
| C. proximus (Hochst. ex A. Rich) Stapf. | Poaceae | Mahareb | Leaves | Decoction | Against renal colic, fever, spasm, prostate inflammation and helminthiasis | [30,52] |
| G. tenax (Forssk.) Fiori. | Tiliaceae | Godeim | Fruits | Powder, maceration, infusion, poultice | Antimalarial, skin diseases, and for anemia | [9,53,54] |
| S. birrea (A. Rich.) Hochst. | Anacardiaceae | Humeid | Stem bark | Powder | Antihelminthics, spasms, diarrhea, and wounds | [10,11,14] |
| H. thebaica (L.) Mart. | Aracaceae | Doum | Fruits | Maceration | Against splenomegaly, trachoma, and wounds | [11,55] |
| G. bicolor Juss. | Malvaceae | Basham | Roots | Decoction, poultice | Against postural skin lesions and to facilitate labor | [56] |
| G. senegalensis J. F. Gmel. | Combretaceae | Karkade | Leaves, roots | Maceration | Antimalarial, fever, leprosy, dysentery, respiratory infections, GIT disorders, chest infection, and rheumatic pain | [8,57,58] |
| B. salicifolia Oliv. | Capparidaceae | Hilla | Seeds | Decoction, dessert | Against stomach ailments, diabetic, as food additive and to increase lactating and contraceptive | [62] |
| H. subdariffa L. | Malvaceae | Tella | Bark | Maceration | Against cough and malaria | [51] |
| C. ochracea L. | Combretaceae | Karkade | Sepals | Maceration, decoction | Against hypertension, colds, fever, antispasmodic and antimicrobial | [30,59-61] |
| T. indica L. | Fabaceae | Ardeh | Fruits | Infusion | Against constipation, fever, malaria and jaundice | [10,23,63] |
| O. insignis Del. | Anacardiaceae | Tagul | Bark, roots | Decoction | Against pharyngitis and stomach ache | [10,51] |
| C. obtusifolia L. | Fabaceae | Kewal | Leaves | Paste | Diuretic, anti-HIV-1 and jaundice | [24,25,64] |
| B. aegyptiaca (L.) Del | Balanitaceae | Al-Laloub | Fruits, seeds, leaves | Maceration | Against constipation, jaundice, dysentery, rheumatic pain, diabetic, helminthics, tumors, and wounds | [8,9,14,42,65-67] |
| O. basilicum L. | Lamiaceae | Al-Rehan | Fruits, leaves | Infusion | Against jaundice and as demulcent | [8] |
| A. senegalensis Pers. | Annonaceae | Giishta | Fruits, leaves | Decoction | Against sleeplessness, antacne, antihelminthic, and arthritis | [68-70] |

HIV-1=Human immunodeficiency virus type 1, GIT=Gastrointestinal, A. javanica=Aerva javanica, A. leiocharp=Anogeissus leiocharp, A. seyal=Acacia seyal, A. hispida=Acanthospermum hispida, A. nilotica=Acacia nilotica, A. Senegal=Acacia Senegal, A. bracteata=Aristolochia bracteata, A. digitata=Adansonia digitata, B. senegalensis=Guiera senegalensis, C. decidua=Capparis decidua, A. polyacantha=Acacia polyacantha, A. sinkatana=Aloe sinkatana, A. amara=Ablizia amara, A. indica=Azadirachta indica, C. occidentalis=Cassia occidentalis, G. villosa=Grewia villosa, C. quadrangularis=Cissus quadrangularis, C. colynthis=Citrullus colocynthis, C. hartmannianum=Combretum hartmannianum, C. procer=Calotropis procer, C. zambesica=Coron zambesicus, E. abyssinica=Erythrina abyssinica, F. retica=Fagonia retica, L. pyrotechnica=Leptadenia pyrotechnica, M. crassifolia=Maerua crassifolia, M. angolensis=Maerua angolensis, S. persica=Salvadora persica, S. alexandra=Senna alexandrina, C. africana=Kigelia africana, C. glutinosa=Caolaba glutinosa, K. senegalensis=Khaia senagalensis, D. melanoxylon=Dalbergia melanoxylon, T. brownii=Terminalia brownii, C. proximus=Cymbopogon proximus, G. tenax=Grewia tenax, S. birrea=Sclerocarya birrea, H. thebaica=Hyphaene thebaica, G. bicolor=Grewia bicolor, G. senegalensis=Guiera senegalensis, B. salicifolia=Boscia salicifolia, H. subdariffa=Hibiscus subdariffa, T. foenum-graecum=Trigonella foenum-graecum, T. indica=Tamarindus indica, O. insignis=Ozoroa insignis, C. obtusifolia=Cassia obtusifolia, B. aegyptiaca=Balantia aegyptiaca, O. basilicum=Ocimum basilicum, A. senegalensis=Anonna senegalensis, C. senegalensis=Caosia senegalensis, S. persica=Salvadora persica.
anti-inflammatory,[127] acaricidal,[121] and antinociceptive[127] effects. Several bioactive compounds have been isolated from different parts of A. indica [Table 2]. Nimbin and nimbidin representing the main phytoconstituents isolated from the seed of the plant, which have showed several biological properties including antibacterial, antifungal, and anti-inflammatory.[119]

**Khaya senegalensis (Desr.) A. Juss. (Meliaceae)**

*Khaya senegalensis* is extensively used as a traditional medicine in rural areas of Sudan for various ailments [Table 1]. Abuzeid *et al.*[299] described that chloroform extracts of the bark and leaf of *K. senegalensis* exhibited a significant inhibitory effect on *Mycobacterium tuberculosis*. Strong antibacterial activities for different bark extracts against *Salmonella enterica*, *Staphylococcus aureus*, *Streptococcus pyogenes*, *Salmonella typhi*, *Shigella dysenteriae*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* [Table 2] were also reported.[210] In addition, the plant has anti-inflammatory, antidiarrheal, antioxidant, antidiabetic, anticancer, and anthelmintic activities.[205,206,208,209] The observed biological activities might be due to the presence of saponins, tannins, flavonoids, terpenoids, alkaloids, anthroquinones, limonoids, khayanolides, and *p*-anilinophenol, which have been identified in this plant [Table 2].

### Table 2: Main phytochemistry constituents, bioactivity, and pharmacological studies based on folk knowledge of the most active Sudanese medicinal plants

| Plant scientific name | Phytochemistry constituents                                                                                                                                                                                                 | Pharmacological activity/assay                                                                                      | References |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------------|
| *A. javanica* (Burm. F.) Juss. Ex Schult | 3-Hydroxy-4 methoxybenzaldehyde, ursolic acid, (E)-N-(4-hydroxy-3-methoxynaphthenyl)-3-(4-hydroxy-3-ethoxyphenyl) acryl amide, ecysteroids, β-ecdysone, 5-β-2-deoxyintegristerone A, 24-epi-makisterone A, isorhamnetin 3-O-β-[4'''-p-coumaroyl-α-rhamnosyl (1→6) galactoside] | Enzyme inhibition for ulcer (+)⁰ Antibacterial activity (ADM)⁰  
*E. coli* (+)  
*K. pneumonia* (+)  
*P. aeruginosa* (+)  
*S. aureus* (+)  
*S. typhi* (−)  
*S. epidermidis*  
Methicillin-resistant *S. aureus* (+)  
Antifungal (−)⁰ Anthelmintic effect against *H. contortusc*  
Egg hatch inhibition (+)  
Larval development viability (+)  
Anthelmintic effect⁰  
*O. ochengi* (+)  
*C. elegans* (+)  
Anthelmintic effect⁰  
Strongyloides papillosus (+)  
*G. pachycelis* (+)  
*Cooperia curticei* (+)  
Oesophagostomum columbianum (+) | [76-79] |
| *A. leiocarpus* (DC.) Guill. and Perr. | Alkaloids, tannins, flavonoids, saponins, phlobatannins, terpenes, ellagic, gentisic and gallic acids | Anthelmintic effect against *H. contortusc*  
Egg hatch inhibition (+)  
Larval development viability (+)  
Anthelmintic effect⁰  
*O. ochengi* (+)  
*C. elegans* (+)  
Anthelmintic effect⁰  
Strongyloides papillosus (+)  
*G. pachycelis* (+)  
*Cooperia curticei* (+)  
Oesophagostomum columbianum (+) | [80-85] |
| *A. seyal* Del. | Gum arabic: Complex polysaccharides containing calcium, magnesium, potassium salts, protein, gallic, ellagic and chlorogenic acids | Antimalarial activity (−)⁰ Brine shrimp toxicity (−)⁰ | [12,86-89] |
| *A. hispidum* Schrank. | Phytosterols, lactones sesquiterpenoids beta-caryophyllene, α-bisabolol, germacrene D | Antiplasmodial activity⁰ Growth inhibition assay (*P. falciparum*) (+)  
Antibacterial activity (ADM and BMM)⁰  
*E. coli* (−)  
*S. aureus* (−)  
Molluscicidal effect⁰  
*B. peregrine* (+)  
Antitrypanosomal activity⁰  
*T. brucei brucei* (+)  
Antileishmanial activity⁰  
*L. mexicana mexicana* (+) | [90-94] |
| *A. senegal* (L.) Willd | Gum arabic, n-alkanes, fatty alcohols, fatty acids | Antibacterial activity (ADM and BMM)⁰  
*E. coli* (−)  
*S. aureus* (−)  
*S. typhi* (−)  
Antifungal activity (ADM)  
*C. albicans* (+)  
*A. niger* (+) | [87-89,95,96] |

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Table 2: Contd...

| Plant scientific name | Phytochemistry constituents | Pharmacological activity/assay | References |
|-----------------------|-----------------------------|-------------------------------|------------|
| *A. nilotica* (L.) Willd. ex Del. | Alkaloids, flavonoids, tannins and saponins, gallic acid, kaempferol, umbelliferone, niloticane | Antibacterial activity (ADM and BMM)\(^c\)
  - *E. coli* (+)
  - *S. aureus* (+)
  - *S. typhi* (+)
Antifungal activity (ADM)\(^c\)
  - *C. albicans* (+)
  - *A. niger* (+)
Antimutagenic activity (+)\(^p\)
Cytotoxic activity (+)\(^p\)
Antioxidant activity (DPPH) (+)\(^p\)
Anti-inflammatory activity (+)\(^c\) | [18-20,95,97,98] |
| *A. bracteolata* Lam. | Alkaloids, saponins, glycosides, steroids, tannins; phenolics, aristolochic acid, leucasin | Wound healing effect (+)\(^c\)
Antidote activity (+)\(^p\) | [99,100] |
| *A. digitata* L. | Terpenoids, flavonoids, sterols, vitamins, amino acids, carbohydrates, lipids, isopropyl myristate, nonanal, procyanidins, tannins, phlobatannins, cardiac glycosides, saponins | Analgesic effect (+)\(^c\)
Antipyretic activity (+)\(^c\)
Antibacterial activity (MIC)\(^c\)
  - *E. coli* (+)
  - *P. aeruginosa* (−)
  - *B. subtilis* (+)
  - *Salmonella* sp. (+)
  - *B. anthracis* (+)
Antifungal activity\(^c\)
  - *C. albicans* (−)
  - *Mucor* sp. (−)
Antiviral activity (MIC) (+)\(^c\)
Antibacterial activity (MIC)\(^p/c\)
  - *B. cereus* (+)
  - *K. pneumonia* (+)
  - *E. coli* (+) | [101-107] |
| *B. senegalensis* (Pers.) Lam. | Glucosinolates, glucocapparin, protein, carbohydrates, fatty acids: palmitic, stearic, and linoleic acids | Insecticidal activity\(^c\)
  - *C. serratus* (+)
  - *C. maculatus* (+)
Antihemolytic activity (+)\(^p\) | [28,108-110] |
| *C. decidua* (Frossk) Edgew. | Fatty acids, flavones, alkaloids, isothiocyanate glucoside | Antidiabetic activity (+)\(^p\)
  - *A. flavus* (−)
Antibacterial activity (MIC)\(^p/c\)
  - *B. cereus* (+)
  - *K. pneumonia* (+) | [111-113] |
| *A. polyacantha* Willd. | Amino acids, tannins, phenolics | Anthelmintic assay\(^c\)
  - *C. elegans* (+)
Antimalarial activity\(^c\)
  - *P. falciparum* (−) | [84,85,114-116] |
| *A. sinkatana* Rey. | Anthraquinones, monosaccharides, anthrones, aloin, aloinoside, microodontin | Antidiabetic activity\(^c\)
  - Hemoglobin-δ-gluconolactone assay (+)
  - BSA assay (+) | [29,117,118] |
| *A. amara* (Roxb.) Boiv. | Budmunchianine A, steroids, alkaloids, saponins, tannins, cardiac glycosides, carbohydrates, flavonoids, terpenoids, glycosides, quinones | Antibacterial activity (MIC)\(^p/c\)
  - *A. flavus* (+)
Antifungal activity (MIC)\(^c\)
  - *Fusarium laceratum* (+)
  - *A. flavus* (−) | [119,120] |

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### Table 2: Contd...

| Plant scientific name | Phytochemistry constituents | Pharmacological activity/assay | References |
|-----------------------|----------------------------|--------------------------------|------------|
| *A. indica* J.Juss.   | Nimbidin, nimbin, nimbolide, gedunin, mahmoodin, octadecanoic acid-3,4-tetrahydrofurran diester, azadirachtin, limonoids, triterpenoids, tetranortriterpenoids, azadiracthlide, aeroxazadiracthltide, polysaccharides, condensed tannins: gallic acid, gallocatechin, epicatechin, catechin, epigallocatechin | Brine shrimp toxicity (−)↑
Antiparasitic activity↑
*S. scabiei* (+)
Myobia musculi Schranck (+)
*Myocoptes musculinus* Koch (+)
Neuroprotective effects (↑)↑
Antimalarial activity↑
P. falciparum (+)
Anti-inflammatory (↑)↑
Antinociceptive (↑)↑
Antibacterial activity (ADM)↑
*E. coli* (−)
Acaricidal activity
*S. scabiei* var. *cuniculi* (+)↑ | [32,86,121-130] |
| *C. occidentalis* L. | Emodin, chrysophanol, saponins, flavonoids, tannins, resins, anthraquinones, cardiac glycosides, chrysoeriol, essential oils, funiculosin, quercetin, rhein, rubrofusarin, sitosterols, tannins, xanthorine | Anthelmintic activity↑
*H. gallinarum* (+)
*R. tetragona* (+)
Catatropis sp. (+)
Anti-inflammatory (↑)↑
Anticancer↑
Chymotrypsin inhibitory activity (+)
Hepatoprotective effect (↑)↑
Antioxidant (DPPH) (↑)↑
Antibacterial activity↑
*B. subtilis* (+)
*E. coli* (−)
*P. aeruginosa* (−)
*S. aureus* (−) | [131-137] |
| *G. villosa* Willd. | Harman, harmine, harmol, harmalol, harmaline, monosaccharides, hydrocarbons, sterols, α-amyрин, uvaol, ursoolic acid, hydroxyuvaol, quinovic acid, β-sitosterol-3-O-glucoside | Anticancer (+)↑
Antioxidant (DPPH) (↑)↑ | [138-142] |
| *C. quadrangularis* L. | Steroids, terpenoids, quercetin, resveratrol, sterols, Vitamin C, tannins, iridoids 6-O-[2,3-dimethoxy]-trans-cinnamoyl catalpol, 6-O-meta-methoxy-benzoyl catalpol, iridoid picroside, quadrangularin A, pallidol, quercitrin, β-sitosterol, β-sitosterol glycoside | Antihemorrhoid effect (↑)↑
Fatty liver disease (↑)↑
Antibacterial activity↑
*B. subtilis* (+)
*B. cereus* (+)
*S. aureus* (+)
Antioxidant (DPPH) (↑)↑
Antiviral activity↑
HSV 1 and HSV 2 (+)
Anticancer activity (↑)↑
Antioxidant (DPPH) (↑)↑
Antidiabetic (↑)↑
Hypolipidemic (seed bowder) (+)
Antibacterial↑
*S. aureus* (+)
Anti-inflammatory activity (↑)↑
Analgesic activity (↑)↑ | [143-148] |
| *C. colocynthis* (L.) Schrad. | Tannins, saponins, cucurbitacins, cucurbitacin glucosides, phenolic acids: ferulic, vanillic, *p*-coumeric, gallic and *p*-hydroxy benzoic acids, chlorogenic acid, flavonoids: quercetin, myricetin, catechin | Contd.. | [36,149-154] |
## Table 2: Contd...

| Plant scientific name          | Phytochemistry constituents                                                                 | Pharmacological activity/assay                                                                 | References |
|--------------------------------|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|------------|
| **C. hartmannianum** Schweinf.  | Flavonoids, phenanthrene, tannins, unsaturated sterol, triterpenes, saponins, carbohydrates | Antimalarial activity<sup>c</sup>  
  *P. falciparum* (+)  
  Antiviral activity<sup>c</sup>  
  HIV-1 reverse transcriptase inhibitory assay (−)  
  Anticancer activity<sup>c</sup>  
  Tyrosine kinase inhibitory assay (+)  
  Antitrypanosomal activity<sup>c</sup>  
  *Trypanosoma brucei rhodesiensi* (−)  
  T. cruzi (−)  
  Antioxidant (DPPH) (+)<sup>c</sup>  
  Anticercarial activity (+)<sup>c</sup>  | [34,155-158] |
| **C. procera** (Ait.) Ait. f.   | Phenolics, flavonoids, flavonoid glycosides, latex, cardenolides, triterpenoids, alkaloids, resins, anthocyanins, tannins, saponins | Antioxidant (DPPH) (+)<sup>c</sup>  
  Antibacterial activity (ADM and MIC)<sup>c</sup>  
  *B. pumilus* (+)  
  *E. coli* (−)  
  Antifungal activity<sup>c</sup>  
  *A. niger* (−)  
  *F. oxysporum* (+)  
  Anthelmintic activity<sup>c</sup>  
  *H. contortus* (+)  | [159-162] |
| **C. zambesicus** Mull-Arg.     | Diterpenoids, crotozambefurans, crotonadiol, abiatane diterpenoids, quinines, triterpenoids, flavonoids, labdane, clerodane, trachylobane diterpenes, quercetin-3-O-β-6″ (p-coumaroyl) glucopyranoside-3′-methyl ether, tiliroside, apigenin-6-C-glucoside | Antimalarial activity<sup>c</sup>  
  *P. falciparum* (+)  
  Anticancer activity<sup>c</sup>  
  Tyrosine kinase inhibitory assay (+)  
  Antiviral activity  
  HIV-1 reverse transcriptase inhibitory assay (−)  
  Antidiabetic activity (−)<sup>c</sup>  
  Kidney protective effect (−)<sup>c</sup>  
  Antioxidant (DPPH) (+)<sup>c</sup>  
  Anti-inflammatory (−)<sup>c</sup>  
  Analgesic (+)<sup>c</sup>  
  Antipyretic (+)<sup>c</sup>  
  Anticancer activity<sup>c</sup>  
  Antibacterial activity (ADM)<sup>c</sup>  
  *B. megaterium* (+)  
  Antitrypanosomal activity<sup>c</sup>  
  *T. brucei brucei* (+)  
  Cytotoxic activity (+)<sup>p</sup>  
  Anti-HIV-1 (+)<sup>p</sup>  
  Activity against *M. tuberculosis* (+)<sup>c</sup>  
  Antimalarial activity<sup>c</sup>  
  *P. falciparum* (+)  
  Antidiabetic activity (+)<sup>p</sup>  
  Anticancer activity<sup>c</sup>  
  Anthelmintic activity<sup>c</sup>  
  Endocrinological effects (+)<sup>p</sup>  
  Analgesic (+)<sup>c</sup>  
  Antipyretic (+)<sup>c</sup>  
  Anticancer activity<sup>c</sup>  
  Antithrombogenic effect<sup>c</sup>  | [34,38,39,163-166] |
| **E. abyssinica** L.            | Alkaloids: erythraline, erysocine, erysotrine, 8-oxoerythraline and 11-methoxyersodine, abyssinone –V  
  Coumestan: Erythribyssin N, benzofurans: erythribyssin F, erythribyssin H, sigmoidin K, isosojagol, eryvarin Q, eryroegin F, eryvarin R | Tyrosine kinase inhibitory assay (+)  
  Antiviral activity  
  HIV-1 reverse transcriptase inhibitory assay (−)  
  Antidiabetic activity (−)<sup>c</sup>  
  Kidney protective effect (−)<sup>c</sup>  
  Antioxidant (DPPH) (+)<sup>c</sup>  
  Anti-inflammatory (−)<sup>c</sup>  
  Analgesic (+)<sup>c</sup>  
  Antipyretic (+)<sup>c</sup>  
  Anticancer activity<sup>c</sup>  
  Antibacterial activity (ADM)<sup>c</sup>  
  *B. megaterium* (+)  
  Antitrypanosomal activity<sup>c</sup>  
  *T. brucei brucei* (+)  
  Cytotoxic activity (+)<sup>yp</sup>  
  Anti-HIV-1 (+)<sup>yp</sup>  
  Activity against *M. tuberculosis* (+)<sup>c</sup>  
  Antimalarial activity<sup>c</sup>  
  *P. falciparum* (+)  
  Antidiabetic activity (+)<sup>p</sup>  
  Anticancer activity<sup>c</sup>  
  Anthelmintic activity<sup>c</sup>  
  Endocrinological effects (+)<sup>p</sup>  
  Analgesic (+)<sup>c</sup>  
  Antipyretic (+)<sup>c</sup>  
  Anticancer activity<sup>c</sup>  
  Antithrombogenic effect<sup>c</sup>  | [34,167-171] |
| **F. cretica** L.               | Triterpenene, saponins, saponins glycosides, linoleic acid, methyl triacontanoate, taraxerol, β-amyrin acetate, oleanolic aldehyde acetate, octacosonic acid, triacontanoic acid, taraxerone | Anticaleral activity<sup>c</sup>  
  Anthelmintic activity<sup>c</sup>  
  Endocrinological effects (+)<sup>p</sup>  | [172-179] |

*Contd..*
Table 2: Contd...

| Plant scientific name | Phytochemistry constituents                                                                 | Pharmacological activity/assay                                                                 | References |
|------------------------|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|------------|
| *L. pyrotechnica* (Forssk. DC.) | Flavonoids, flavonoids glycosides: kaempferol-3-O-α-1-rhamnopyranosyl (1″→6″)-O-β-D-glucopyranoside, kaempferol-3-O-β-D-rhamnopyranosyl (1″→6″)-O-β-D-glucopyranoside, teixasin-7-O-β-D-glucopyranoside, kaempferol-3-O-β-D-gluco pyranoside, kaempferol, carbohydrates, glycosides, saponins, pregnane glycosides, alkaloids: pyridine, pyrrole, pyrazine and indole types | Antibacterial activity (ADM)\(^c\)
S. aureus (+)
S. epidermidis (+)
Anticancer activity\(^c\)
Potato disc assay (+)
Antioxidant (DPPH and ABTS)\(^c\)
Anti-inflammatory
Lipoxygenase inhibitory activity (+) | [180-184] |
| *M. crassifolia* Forssk. | Linoleic acid, 1, 23 dimethoxy tricosa-6-one, triacontane, ceryl alcohol, lupeol palmitate, lupeol acetate, β-sitosterol palmitate, α-amyrin, 6-N-methyl-9-β-D-glucoside adenine, 3,4,5-trimethoxyphenol-1-O-β-D-glucopyranoside, guaiacglycerol, ionol glucoside | Antibacterial activity (ADM)\(^c\)
P. aeruginosa (−)
Antimalarial activity\(^c\)
P. falciparum (−)
Antitrypanosomal activity\(^c\)
T. brucei brucei (−)
T. cruzi (−) | [185-190] |
| *M. angolensis* DC. | Tannins, saponins, flavonoids, cardiac glycosides, alkaloids: l-stachydrine and l-3-hydroxystachydrine | Anxiolytic effect (+)\(^c\)
Sedative effect (+)\(^c\)
Antioxidant (DPPH) (+)\(^c\)
Antibacterial activity (ADM)\(^c\)
S. aureus (+)
S. pyogenes (+) | [191-194] |
| *S. persica* L. | 2-acetyl-3-methylindole, sodium 1-O-benzyl-β-D-glucopyranoside-2-sulphate (salvadoside), 5,5′-dimethoxylicariciselin 4,4′bis-O-β-D-glucopyranoside (salvadora), syringin, liriodendrin, sitosterol 3-O-glucopyranoside | Antimalarial activity\(^c\)
P. falciparum (+)
Antioxidant (DPPH) (+)\(^c\)
Antitrypanosomal activity\(^c\)
T. brucei rhodesiense (−)
T. cruzi (−)
Antifungal activity\(^c\)
C. albicans (+) | [34,45,46,155] |
| *S. alexandrina* Mill. *(C. senna* L.) | Anthranoids, madagascin (3-isopentenyloxyemodin), 3-geranyloxyemodine | Laxative effect\(^c\)
Cytotoxic activity (−)\(^c\)
Carcinogenic effect (−)\(^c\)
Antioxidant (DPPH) (+)\(^c\)
Anticandidal activity\(^c\)
C. albicans strains (+)\(^c\)
Antiulcerogenic (+)\(^c\)
Anti-inflammatory activity (+)\(^c\)
Antioxidant (DPPH) (+)\(^c\) | [195-198] |
| *K. Africana* (Lam.) Benth. | Limonoids, alkaloids, lapachols, phenolic acids, irridoids, flavonoids, naphthoquinones, steroids | | [199-202] |
| *C. glandulosa* Forssk. | Alkaloids, terpenes, sterols, flavonoids: kaempferol-4′-phenoxy-3,3′,5′-trimethylether, rhamnocitrin-4′- (4-hydroxy-3-methoxy) phenoxy-3-methyl ether, rhamnocitrin-3-O-neohesperidose-4′-O-rhamnoside, 4-methoxy-benzyledehyde, kaempferol-3-methylthether, stachydrine | | [203,204] |
### Table 2: Contd...

| Plant scientific name | Phytochemistry constituents | Pharmacological activity/assay                                                                 | References    |
|-----------------------|----------------------------|------------------------------------------------------------------------------------------------|---------------|
| *K. senegalensis* (Desr.) A. Juss. | Saponins, tannins, aldehyde, phlobatannins, flavonoids, terpenoids, alkaloids, cardiac glycoside, anthroquinones, limonoids, khayanolides, p-anilinophenol | Anti-inflammatory activity (+)  
Antidiarrheal effects (+)  
Antioxidant (DPPH) (+)  
Antibacterial activity (ADM/MIC)  
S. enterica (+)  
S. aureus (+)  
S. pyogenes (+)  
S. typhi (+)  
S. dysenteriae (+)  
K. pneumonia (+)  
P. aeruginosa (+)  
Anticancer activity (+)  
MCF-7, SiHa and Caco-2  
Anthelmintic activity (+)  
Antidiabetic activity (+)  | [205-210] |
| *D. melanoxylon* Guill. and Perr | Flavonoids, terpenes, alkaloids, steroidal saponins, tannins, phenols, quinines | Antimalarial activity  
P. falciparum (−)  
Antibacterial activity (ADM)  
B. subtilis (+)  
E. coli (+)  
K. pneumonia (−)  
P. aeruginosa (+)  
Salmonella typhimurium (−)  
S. aureus (+)  
Y. pestis (−)  
Antifungal activity  
C. albicans (+)  
A. niger (+)  | [211-213] |
| *T. brownii* Fresen. | Terminalianone, triterpenoids, ellagic acid derivatives | Antibacterial activity (ADM)  
S. aureus (+)  
E. coli (+)  
P. aeruginosa (+)  
K. pneumonia (±)  
S. typhi (+)  
B. anthracis (+)  
Antifungal activity  
C. albicans (+)  
C. neoformans (+)  | [214-216] |
| *C. proximus* (Hochst. ex A. Rich) Stapf. | Essential oils: Piperitone, elemol, eudesmol, terpineol, limonene | Brine shrimp toxicity (−)  
Anti-inflammatory activity (−)  
Antibacterial activity (ADM)  
B. cereus (+)  
S. choleraesuis (+)  
Antioxidant (DPPH) (+)  
Antifungal activity  
C. albicans (−)  
C. utilis (−)  
S. cerevisiae (−)  | [217,218] |
| *G. tenax* (Forsk.) Fiori. | Flavonoids, flavonoid glycosides, phenolic acids; β-sitosterol, β-sitosteryl acetate, β-amyrin, β-amyrin acetate; 5 α, 8 α-epidioxyergosta-6,22-diene-3 β-ol; 5 α, 8 α-epidioxyergosta-6,9 (11),22-trien-3 β-ol, α-taraxerol, betulin, stigmasterol, oleanolic acid, stigmastanol 3-O-β-D-glucoside | Hepatoprotective effect (+)  
Antibacterial activity (ADM)  
S. aureus (−)  
S. typhi (−)  
S. dysenteriae (−)  
V. cholerae (−)  
E. coli (−)  | [219-221] |
| Plant scientific name | Phytochemistry constituents | Pharmacological activity/assay | References |
|-----------------------|----------------------------|-------------------------------|------------|
| S. birrea (A.Rich.) Hochst. | Procyanidins, tannins, alkaloids, quercetin 3-O-α- (5”-galloyl)-arabinofuranoside, epicatechin derivatives | Antioxidant (DPPH) (+) ¹  Antioxidant activity ²  Antidiabetic activity ³  Antibacterial activity (ADM) ⁴  B. subtilis (+)  E. coli (+)  K. pneumonia (+)  S. aureus (+)  Antidiarrheals activity (+) | [155,222-225] |
| H. thebaica (L.) Mart. | Minerals, proteins, fatty acids, essential oils, linoleic acid, saponins, coumarins, hydroxycinnamates, flavonoids | Antioxidant (DPPH) (+) ²  Antihypertensive effect (+) ³  Antibacterial activity (ADM) ⁴  S. aureus (+)  B. subtilis (+)  E. coli (−)  L. monocytogenes (−)  P. aeruginosa (+)  S. typhi (+)  Antifungal activity ⁵  A. niger (+)  C. albicans (+) | [226-229] |
| G. bicolor Juss. | Tannines, triterpenoids: lupeol, etulin, β-sitosterol, β-sitosterol-3-O-glucoside; alkaloids: harmaran, 6-methoxyharman, 6-hydroxyharman | Anthelmintic assay ⁶  C. elegans (+)  Antibacterial activity (ADM) ⁴  P. aeruginosa (+)  E. coli (+)  S. aureus (+)  B. subtilis (+) | [56,84,230] |
| G. senegalensis J.F.Gmel. | Resins, alkaloids, tannins, saponins, glycosides, terpenes, galloylquinic acids, flavonoids: catechin, myricitrin, rutin, quercetin | Antioxidant (DPPH) (+) ²  Antitrypanosomal activity ⁷  T. brucei brucei (+)  Antimalarial activity ⁸  P. falciparum (+)  Acaricidal activity ⁹  H. anatolicum (+) | [126,155,231-234] |
| B. salicifolia Oliv. | Boscialin, boscialin 4’-O-glucoside, flavonoids: rhamnocitrin 3-O-β-neohesperidoside, rhamnetin 3-O-β-neohesperidoside, rhamnocitrin 3-O-β-glucopyranoside | Antimalarial activity ⁹  P. falciparum (+)  P. berghei (+)  | [235-237] |
| H. siphonifera L. | Organic acids: Hydroxycitric acid, hibiscus acid; phenolic acids: Protocatechueic acid, chlorogenic acids, anthocyanins, polysaccharides, flavonoids | Antibacterial activity ⁷  S. aureus (+)  K. pneumonia (+)  P. aeruginosa (+)  A. baumannii (+)  Antifungal activity ⁹  C. albicans (−)  Antipyretic activity (+) ⁸  Anti-inflammatory activity (+) ⁸  Antioxidant (DPPH) (+) ²  Antidiabetic activity (+) ³  Anticancer activity (+) ⁹  Antihypertensive activity (+) ⁹  Hepatoprotective effect (+) ⁹ | [61,98,238-246] |

Contd..
Table 2: Contd...

| Plant scientific name | Phytochemistry constituents | Pharmacological activity/assay | References |
|-----------------------|----------------------------|--------------------------------|------------|
| *T. foenum-graecum* L. | Tannin, protein, lipids, glycolipids, phospholipids | Antidiabetic activity (+)<sup>+</sup><br>Wound healing activity (+)<sup>+</sup><br>Larvicidal activity (+)<sup>−</sup><br>Antimalarial activity (+)<sup>−</sup><br>Anti-snake venom effects (+)<sup>−</sup><br>Immunomodulatory effects (+)<sup>−</sup><br>Antidiabetic activity (+)<sup>−</sup> | [247-252] |
| *T. indica* L. | Polysaccharides, phenolic acids, flavonoids, anthocyanidins, tannins | Antimalarial activity (−)<sup>c</sup><br>Brine shrimp toxicity (−)<sup>c</sup><br>Wound healing effects (+)<sup>c</sup><br>Antioxidant (DPPH) (+)<sup>c</sup><br>Anti-snake venom effects (+)<sup>c</sup><br>Immunomodulatory effects (+)<sup>c</sup><br>Antidiabetic activity (+)<sup>c</sup> | [86,253-258] |
| *O. insignis* Del. | Triucallane triterpenes, alk (en) yl phenols, macrolide, 6-pentadecysaliclyc acid, tannins, flavonoids, cardiac glycosides, steroids, alkaloids | Anthelmintic effect (+)<sup>c</sup><br>Cytotoxic activity (+)<sup>c</sup><br>Antifouling activity (+)<sup>c</sup><br>Antileishmanial<sup>−</sup><br>L. donovani (−)<sup>c</sup><br>Antitrypanosomal<sup>−</sup><br>*T. brucei brucei* (−)<sup>c</sup><br>Antitumor activity (−)<sup>−</sup><br>Antitrypanosomal<sup>−</sup><br>*E. coli*<br>*S. typhi*<br>*V. cholerae*<br>*K. pneumonia* | [259-267] |
| *C. obtusifolia* L. | Polysaccharides: galactomannan, homogalacturonan; anthraquinones, benzyl-β-resorcylate glycosides, flavonoids, triterpenoids, anthrones | Antioxidant (DPPH) (+)<sup>+</sup><br>Hypolipidemic activity (+)<sup>−</sup><br>Neuroprotective effect (+)<sup>−</sup><br>α-Amylase activity (−)<sup>−</sup><br>Lipase activity (−)<sup>−</sup><br>Protease activity (−)<sup>−</sup><br>Antitumor activity (+)<sup>−</sup><br>Antihypertensive effect (+)<sup>−</sup><br>Laxative effect (−)<sup>−</sup><br>Antidiabetic activity (+)<sup>−</sup><br>Molluscicidal activity (+)<sup>−</sup><br>Antioxidant (DPPH) (+)<sup>−</sup><br>Anticancer activity (+)<sup>−</sup><br>Antidiabetic activity (+)<sup>−</sup><br>Larvicidal activity (+)<sup>−</sup><br>Anti-inflammatory (−)<sup>−</sup><br>Antinociceptive (−)<sup>−</sup><br>Antioxidant<sup>−</sup><br>ORAC assay (+) and DPPH (+) | [268-275] |
| *B. aegyptiaca* (L.) Del | Balanitins, saponins, yamogenin glycosides, ascorbic acid, coumarins, alkaloids, flavonoids, flavonoid glycosides: isorhamnetin-3-O-robinobioside, isorhamnetin-3-O-rutinoside | Molluscicidal activity (+)<sup>−</sup><br>Antioxidant (DPPH) (+)<sup>−</sup><br>Anticancer activity (+)<sup>−</sup><br>Antidiabetic activity (+)<sup>−</sup><br>Larvicidal activity (+)<sup>−</sup><br>Anti-inflammatory (−)<sup>−</sup><br>Antinociceptive (−)<sup>−</sup><br>Antioxidant<sup>−</sup><br>ORAC assay (+) and DPPH (+) | [276-281] |
| *O. basilicum* L. | Phenolic acids: rosmarinic, chicoric, caffeic and caftaric acids; anthocyanins, polysaccharides<<br>Essential oils: methyl chavicol, eugenol, linalool, camphor and methyl cinnamate | Antimarial activity<sup>−</sup><br>Antibacterial activity (ADM and MIC)<sup>−</sup><br>Antifungal activity (ADM and MIC)<sup>−</sup><br>B. theobromae<br>Rhizopus solani<sup>−</sup><br>Antibacterial activity (ADM and MIC)<sup>−</sup><br>Antifungal activity (ADM and MIC)<sup>−</sup><br>A. niger<br>M. muscor<br>F. solani<br>B. theobromae<br>Rhizopus solani<sup>−</sup> | [282-290] |
Table 2: Contd...

| Plant scientific name | Phytochemistry constituents | Pharmacological activity/assay | References |
|-----------------------|----------------------------|--------------------------------|------------|
| *A. senegalensis* Pers. | Alkaloids, sapogenins, tannins, flavonoids, terpenes: germacrene D, β-caryophyllene, α-humulene | Antitypanosomal activity*[^8] | [70,291-296] |

[^8]: Assays carried out for isolated compounds.

[^6]: Assays carried out for plant crude extracts.

[^7]: Assays carried out for plant essential oils. ADM = Agar diffusion method.

BM = Broth microdilution method, DPPH = 1,1-Diphenyl-2-picrylhydrazyl, MIC = Minimum inhibition concentration, HSV = Herpes simplex-virus type 1.

BSA = Glucose-bovine serum albumin, *A. javanica* = Aerva javanica, *A. leucopappus* = Anogeissus leucopappus, *A. seyal* = Acacia seyal, *A. hispidum* = Acanthopanax hispidum, *A. nilotica* = Acacia nilotica, *A. Senegal* = Acacia Senegal, *A. bracteata* = Aristolochia bracteata, *A. digitata* = Adansonia digitata, *B. senegalensis* = Boisca senegalensis, *C. decidua* = Capparis decidua, *A. polyantha* = Acacia polyantha, *A. kirkiana* = Acacia kirkiana, *A. amara* = Albizia amara, *A. indicia* = Azadirachta indica, *C. occidentalis* = Cassia occidentalis, *G. vullosa* = Grewia vullosa, *C. quadrangularis* = Cissus quadrangularis, *C. colynctis* = Citrus colynctis, *C. hartmannianum* = Combretum hartmannianum, *P. procera* = Cardioficus procera, *C. zambesicus* = Calospermum zambesicus, *E. abyssinica* = Erythrina abyssinica, *F. cretica* = Fagonia cretica, *L. pyrotechnica* = Leptadenia pyrotechnica, *M. crassifolia* = Maerua crassifolia, *A. angolensis* = Maerua angolensis, *S. persica* = Salvia persica, *S. alexandrina* = Senna alexandrina, *K. Africana* = Kigelia Africana, *C. glandulosa* = Cadaba glandulosa, *K. senegalensis* = Khaya senegalensis, *D. melanoxylon* = Dalbergia melanoxylon, *T. brownii* = Terminalia brownii, *C. proximus* = Cymbopogon proximus, *G. tenax* = Grewia tenax, *B. aegyptiaca* = Boscia aegyptiaca, *G. bilicola* = Grewia bicolor, *S. senegalensis* = Saxaul senegalensis, *B. salicifolia* = Bosia salicifolia, *H. brownii* = Hibiscus brownii, *C. foenum-graecum* = Trigonella foenum-graecum, *T. indica* = Tamarindus indica, *O. insignis* = Ozoroa insignis, *C. obtusifolia* = Cassia obtusifolia, *B. apiculata* = Balanites apiculata, *O. basilicum* = Ocimum basilicum, *A. senegalensis* = Annona senegalensis, *E. coli* = Escherichia coli, *K. pneumoniae* = Klebsiella pneumonia, *P. aeruginosa* = Pseudomonas aeruginosa, *S. aureus* = Staphylococcus aureus, *S. typhi* = Salmonella typhi, *A. flavus* = Aspergillus flavus, *C. albicans* = Candida albicans, *E. coli* = Escherichia coli, *K. pneumoniae* = Klebsiella pneumonia.

**Ocimum basilicum L. (Lamiaceae)**

*Ocimum basilicum* is considered as one of the major genera of the Lamiaceae family. It grows in several regions all over the world. In Sudan, *O. basilicum* grows in the wild and is also cultivated in Northern and Central Sudan.[^50] Traditional healers in the remote areas of Sudan use *O. basilicum* in the form of infusion against jaundice and as demulcent.[^9][^9]

The essential oil of the plant is used in perfumery and in food industry as flavoring agent, as well as in dental and oral products.[^100][^100] *O. basilicum* has shown several biological properties, including antimicrobial, antimalarial, and antioxidant activities.[^282][^282] These pharmaceutical activities could be attributed to essential oil constituents, such as eugenol, linalool, camphor, methyl chavicol, and methyl cinnamate [Table 2].

**Calotropis procera (Ait.) Ait. f. (Asclepiadaceae)**

Conventionally, in Sudan, *Calotropis procera* is used in the form of infusion to treat jaundice, thorn injuries and as mouth detergent, while the paste of the plant is used against scorpion bites and rheumatic pain [Table 1]. *C. procera* has shown antibacterial, antioxidant, antifungal, and antihelmintic activities.[^127][^127] Saponins, tannins, alkaloids, flavonoids classes of compounds are likely to contribute to the reported effects.[^142]

**Hibiscus sabdariffa L. (Malvaceae)**

*H. sabdariffa* is considered one of the medicinal plants having great interest among all Sudanese communities. It has been used in ethnomedicine as herbal drinks in cold and hot beverages and as an herbal medicine. *H. sabdariffa* natural habitat is Southern Sudan, but it is cultivated in many parts of the Sudan. The maceration and decoction of the plant are used against hypertension, colds, fever and as anti-inflammatary and antimicrobial agent [Table 1]. In addition, *H. sabdariffa* calyces are boiled with sugar to produce a drink known as “Karkade.” Pharmacological studies have demonstrated that *H. sabdariffa* extracts showed antibacterial,[^240] antifungal,[^242] antioxidant,[^244] anticancer,[^6][^6][^245] anti-inflammatory,[^241] and hepatoprotective effects.[^243] However, the plant extract did not inhibit the growth of fungi of Candida albicans.[^240] The interesting biological effects might be associated with the presence of phenolic acids, organic acids, and anthocyanins reported in different parts of the plant.[^2]

**Ziziphus spina-christi (L.) Desf. (Rhamnaceae)**

*Z. spina-christi* is a tropical tree of Sudanese origin. The plant has very interesting historical and religious aspects. It is repeatedly mentioned in Muslim as well as Christian traditions and was recorded by pilgrims visiting the Holy Land on numerous occasions. The boiled water extracts of the leaves of *Z. spina-christi* are used by Muslims in the cleaning of a dead body before burial suggesting antibacterial properties. In addition, the plant has been used in mummification by the ancient Egyptians.[^102][^103] It has been suggested that the plant material referred to in the Bible as the “bramble” or “thorns” (Judges 9:14-15), “thorns” (Matthew 27:27-29), and “crown of thorn” (John 19:3-5) might have been derived from *Z. spina-christi*.[^104][^105] The Holy Quran mentions the Lote tree (Cedar) 3 times (XXIV: 16; XIII: 13-18; LVII: 28-32), which was frequently identified as *Z. spina-christi*. Accordingly, this species is highly respected throughout the Middle East, has been widely used as a food and as medicinal as well as an environmental protection plant since ancient times, and is still in use until now.[^102][^107]

*Z. spina-christi* is commonly used in ethnomedicine for the treatment of many illnesses such as digestive disorders, weakness, hepatic disorders, obesity, urinary problems, diabetes, skin infections, fever, diarrhea, or insomnia.[^308] In Sudanese ethnomedicine, the leaves of *Z. spina-christi*
are used for the treatment of malaria.\textsuperscript{[23]} In addition, Michel \textit{et al.} reported an antidiabetic activity of the leaves of \textit{Z. spina-christi} due to their saponin and polyphenol contents,\textsuperscript{[110]} which was supported in pharmacological studies by Glombitza \textit{et al.}, indicating that extracts of \textit{Z. spina-christi} leaves or its main saponin glycoside, christinin-A, improved glucose utilization in diabetic rats.\textsuperscript{[311]} Furthermore, \textit{Z. spina-christi} leaves and fruits are reported to possess antibacterial activity,\textsuperscript{[312,313]} as well as antifungal activity on plant pathogens.\textsuperscript{[314]} In addition, Adzu \textit{et al.} found that root bark extracts showed significant antinociceptive activity in mice and rats.\textsuperscript{[315]}

The phytochemical studies of the \textit{Z. spina-christi} have demonstrated that peptide and cyclopeptide alkaloids such as spinanine-A, tanines, essential oil such as geranyl acetate, methyl hexadecanoate, and methyl octadecanoate, sterols such as β-sitosterol, triterpenoid sapogenins, and saponins such as betulinic acid, flavonoids such as rutin and quercetin derivatives are the main phytoconstituents of this plant.\textsuperscript{[316,317]}

\textbf{Mimosa pigra (Fabaceae)}

\textit{Mimosa pigra} (giant sensitive plant) is a woody shrub, native to the American tropics. Besides its native area, it is very invasive and damaging to agriculture and conservation. In particular, it is problematic in Australia, Africa, and Southeast Asia.\textsuperscript{[318]} It has been introduced to Sudan and its neighboring countries.\textsuperscript{[319]} Apart from this, \textit{M. pigra} is used in the traditional medicine in tropical Africa, Indonesia, Madagascar, and South America for heart problems, head colds, diarrhea, toothaches, eye medicine, and its antimicrobial activity.\textsuperscript{[320,321]} Rakotomalala \textit{et al.} demonstrated the beneficial effect of the leaves of the plant for pulmonary hypertension.\textsuperscript{[322]}

Different phytochemistry constituents including tryptophan, myricetin 3-O-rhamnoseside, quercetin 3-O-hexoside, quercetin 3-O-pentoside, quercetin 3-O-rhamnoseside, kaempferol 3-O-rhamnoseside, kaempferol, apigenin, acacetin, quercetin 3-rutinoside, quercetin 3, 7-diharmnoseside, kaempferol 3,7-diharmnoseside and luteolin 7-arabinoside, quercetin 7-methyl ether, and saponin have been previously described as occurring in \textit{M. pigra}.\textsuperscript{[322-324]}

\textbf{Ixora coccinea L. (Rubiaceae)}

\textit{Ixora coccinea} is a flowering plant native to India and Sri Lanka. \textit{I. coccinea} is used in traditional Sudanese and ayurvedic medicinal systems for the treatment for diarrhea, fever, headache, skin diseases, eye trouble, wounds, sores, and ulcers.\textsuperscript{[325]} Recent reports show that \textit{I. coccinea} has an antidiabetic,\textsuperscript{[326]} antibacterial,\textsuperscript{[327]} anticancer,\textsuperscript{[328]} analgesic, anti-inflammatory,\textsuperscript{[329]} antidiarrheal,\textsuperscript{[330]} hepatoprotective,\textsuperscript{[331]} cardioprotective,\textsuperscript{[332]} antimutagenic,\textsuperscript{[333]} wound healing,\textsuperscript{[334]} and anticancer activities.\textsuperscript{[335]} \textit{I. coccinea} is a source of peptides,\textsuperscript{[336]} triterpenoids,\textsuperscript{[337]} and fatty acids.\textsuperscript{[338]} Recently, we have reported different phenolics in the stem and leaves of \textit{I. coccinea} including chlorogenic acids, proanthocyanidins, flavonoids, and flavonoid glycosides,\textsuperscript{[339]} in addition to the similar bioactive compounds identified previously.\textsuperscript{[340]}

\textbf{Ambrosia maritima L. and Sonchus oleraceus L. (Asteraceae)}

\textit{Ambrosia maritima} and \textit{Sonchus oleraceus}, two multipurpose medicinal plants, are widely distributed weed in Sudan, Senegal, and neighboring countries.\textsuperscript{[341,342]} These plants are extensively used to treat several diseases including virus infections across the African continent.\textsuperscript{[22,341,342]} In Sudan and other countries, \textit{A. maritima} dried herb is used for treatment of hypertension, diabetes, bronchial asthma, spasms, frequent urination, urinary tract infections, and elimination of kidney stones.\textsuperscript{[37,343,344]} This plant is also applied as a molluscicidal component for controlling of the intermediate hosts of Fasciola and Schistosoma.\textsuperscript{[145]} Moreover, some authors have previously reported the antiviral and antifungal activities of \textit{A. maritima}.\textsuperscript{[22,341]} On the other hand, the vegetative shoots of \textit{S. oleraceus} have been frequently used by traditional healers to treat diabetes, diarrhea, pneumonia, and hepatitis.\textsuperscript{[342,346]} Moreover, the plant has cholagogue, laxative, and emollient properties.\textsuperscript{[347]} The antidiabetic, antibacterial, anti-inflammatory, and antioxidant properties of \textit{S. oleraceus} were also reported.\textsuperscript{[342,348,349]} Several bioactive phytoconstituents have been identified in \textit{A. maritima} and \textit{S. oleraceus} including phenols, flavonoids, proanthocyanidins, alkaloids, tannins, terpenes, and steroids.\textsuperscript{[341,346,351-356]}

\textbf{CONCLUSIONS}

In this review, we have showed that local people in Sudan are still relying on traditional medicines to treat several diseases and microbial infections. The information collected in this article demonstrated the existing traditional uses of the most important Sudanese medicinal plants and summarized recent research into the phytochemistry and pharmacology of these plants. The extracts and isolated compounds have been found to possess various biological activities, particularly in the area of antimicrobial, antidiabetic, anticancer, anti-inflammatory, and antioxidant. Although increasing interest has encouraged more studies on the phytochemistry and pharmacology of the Sudanese medicinal plants, there are still many parts where the present knowledge could be improved, for instance, systematic toxicity and safety evaluation, the detailed quantitative data for the bioactive compounds and investigation the structure activity relationships of the isolated and purified active compounds. Moreover, most of the pharmacological studies on medicinal plants have been carried out \textit{in vitro}. Thus, the effectiveness of plant extracts and isolated compounds needs to be further investigated for their efficacy and safety using \textit{in vivo} assays; consequently, benefits could be fairly shared among Sudanese local peoples according to the CBD. It is concluded that traditional medicine should be considered seriously in future researches and projects designed to produce lead compounds and/or biologically active molecules from plant sources.

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\textbf{Conflicts of interest}

There are no conflicts of interest.

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