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MEDICINAL PLANTS OF THE SENEGALESE FLORA WITH CONFIRMED ANTI-LEISHMANIAL ACTIVITIES BY *IN VIVO* AND *IN VITRO* TESTS: A REAL OPPORTUNITY FOR LOCAL MANAGEMENT OF THIS NEGLECTED TROPICAL DISEASE (REVIEW)

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ABSTRACT

Leishmaniasis is a disease caused by protozoan parasites of the Trypanosomatidae family and Leishmania genus. Leishmaniosis is endemic in many countries in Africa, Asia, southern Europe, the Middle East, and Central and South America. For a long time, the treatment of affected individuals has relied mainly on chemotherapy using among others pentavalent antimony derivatives, miltefosine and amphotericin B. However, the numerous side effects, toxicity and high cost of these treatments, as well as the emergence of resistance, pose a major challenge in the treatment of affected individuals, thus necessitating the search for new treatments. Medicinal plants are known to be an inexhaustible source of active molecules. Senegal has a rich plant diversity, including plants traditionally used to treat various diseases. Various compounds and extracts that have demonstrated significant anti-leishmanial activity have been described in the literature. The results of this research should enable a focus on the development of new natural-based treatments. The aim of this review is to list the medicinal plants of Senegalese flora used against leishmaniasis

whose anti-leishmanial activity has been scientifically proven.

KEYWORDS: Leishmaniosis; medicinal plants; Senegalese flora, anti-leishmanial.

1. INTRODUCTION

Neglected tropical diseases (NTDs) with cutaneous manifestations affect the skin and subcutaneous tissues and can lead to disability, disfigurement, stigmatization, and other socioeconomic problems. Among these skin diseases is leishmaniasis, which represents a major public health problem[1], causing significant mortality and morbidity in Africa, Asia, and Latin America. According to the World Health Organization (WHO), leishmaniasis is one of the seven most important tropical diseases and can produce a wide range of clinical conditions, ranging from asymptomatic carriers and benign cutaneous lesions to more serious cases such as the potentially fatal visceral form.[2] With a wide global distribution, leishmaniasis endangers more than one billion people living in endemic areas and particularly affects the poorest populations. The disease is endemic in 97 countries and affects more than 12 million people, with more than 350 million people at risk of infection. Between 700,000 and 1 million new cases are reported each year.[3] The clinical manifestations encountered in humans generally take four forms: localized cutaneous leishmaniasis (LCL), diffuse cutaneous leishmaniasis (DCL), mucocutaneous leishmaniasis (MCL), and visceral leishmaniasis (VL).[4][5] It is estimated that there are 30,000 new cases of visceral leishmaniasis and more than 1 million cases of cutaneous leishmaniasis each year.[6] These parasitic diseases are particularly dangerous in hosts who are immunocompromised (HIV)[7] or suffering from cancer.[8] There is currently no vaccine or prophylactic drug against leishmaniasis. For several years, numerous treatments have been used to manage leishmaniasis (amphotericin B, meglumine antimoniate, miltefosine, paromomycin, pentamidine etc.)

However, although these treatments are expensive, they have numerous side effects, frequent relapses, long treatment times, and high toxicity.[9] In addition, resistance phenomena have emerged, creating a major challenge in the care of affected individuals.[9] Therefore, the search for new active compounds with leishmanicidal properties and low toxicity remains essential. Due to their broad spectrum of biological activity, extracts and essential oils from medicinal plants are widely tested for their antileishmanial activity.[10] Indeed, 25 to 50% of pharmacopoeias worldwide contain plant-based products and drugs derived from natural products.[11] Senegal has a rich plant biodiversity. Approximately, 3750 plant species have

been identified in Senegal, including 250 fungi.[12] Senegalese populations mainly use these plants to satisfy their primary health care needs.

The objective of this review is to identify the plant species of the Senegalese flora for which experimental studies on their antileishmanial effects in vitro and/or in vivo have been carried out.

2. METHODOLOGY

We conducted a bibliographic search in PubMed, Science Direct, Sci-hub, Web of Science, and Google Scholar, using keywords in English and French. The search terms used were: ethnobotanical survey, Senegalese medicinal plants, leishmaniasis, Senegalese flora, cutaneous leishmaniasis, *in vitro* and *in vivo* anti-leishmanial activities. The following publication languages were included: English and French. All plant species were taxonomically validated; the Latin scientific name and family were confirmed using The Plant List (*http://www.theplantlist.org/*) and Plants of The World (Plants of the World Online | Kew Science) websites. The search was conducted from November 16 to January 15, 2026. The text was written using the Mendeley bibliographic insertion system.

3. RESULTS

As shown in **Table 1**, 39 species belonging to 26 different families were identified as having antileishmanial properties.

3.1 The Anacardiaceae family

With more than 200 species divided into 32 genera in the Neotropics, the Anacardiaceae are an ecologically and economically important family of plants. The family includes valuable global fruit and seed crops such as cashew (*Anacardium occidentale L.*) and mango (*Mangifera indica L.)*, and its species are also used in medicine, industrial applications, and much more. The Anacardiaceae family is distributed across almost every continent, from America to Europe, Asia, Africa, and Australia.[27] Anacardiaceae are well represented in Senegal, with around ten genera, including *Lannea*, *Sclerocarya*, and *Pseudospondias*.

1- Mangifera indica L.

Native to eastern India, *M. indica* (mango in Wolof) is found in Senegal from the Guinean region to the Sahel. For a very long time, *M. indica* has been an integral part of tradtional medicine in Africa, Asia, and South America, particularly for its antimicrobial, antifungal,

anticancer, and antiparasitic properties. The methanolic extract of *M. indica* leaves has shown leishmanicidal activity against *L. donovani in vitro* with an IC50 of 2.74 µg/mL.[28]

2- Pseudospondias microcarpa (A. Rich.)

Pseudospondias microcarpa (A. Rich.) (Dologa in Fulani), a Guinean species, is a tree 12 to 15 m tall that is widespread in the Sudanese region. It is very common in the humid forests of Casamance, where it is used in folk medicine to treat infectious lesions[29] and as an analgesic and anti-inflammatory agent.[30] The ethanolic extract of *Pseudospondias microcarpa* stem bark has shown *in vitro* antiparasitic activity against *L. donovani* with an IC50 of 29.9 ± 4.19 µg/mL.[31][32][33]

3- Spondias mombin L.

Spondias mombin L. (ninkom or sob in Wolof) is a tree native to tropical Central America that can grow up to 25 m tall, but rarely reaches 15 m in Senegal. *S. mombin* is best known for its combustible fruit, but the juice obtained from its fresh leaves is used to treat eye diseases in Casamance, while a decoction of the leaves and a macerate of the roots are used to treat diarrhea and painful colic, respectively.[29] Antioxidant and antibacterial actions, acetylcholinesterase inhibition, and anticancer activity have already been reported.[34] Ethyl acetate: chloroform (90:10) and ethyl acetate: methanol (80:20) fractions obtained from the crude hydromethanolic extract (1:4) of S. mombin leaves showed significant antileishmanial activity in vitro.[35] methanol (80:20) fractions obtained from the crude hydromethanolic extract (1:4) of *S. mombin* leaves showed significant *in vitro* antileishmanial activity against *L. chagasi* with respective $_{IC50}$ values of 0.61 µg/mL and 0.27 µg/mL on amastigotes.[35] Antileishmanial activity (IC50 = 81.50 µg/mL) was also demonstrated on hydroethanolic extracts (50:50) from the leaves of the species tested on *L. donovani* promastigotes.[36][37]

3.2 The Annonaceae family

The Annonaceae are represented in Senegal by the genera *Hexalobus, Annona, Uvaria*, and *Xylopia*. This family comprises only trees and shrubs and is found in tropical and subtropical areas. The family has about 123 genera and 2,100 species. The anti-protozoal activity of Annonaceae species in traditional treatments for malaria, Chagas disease and leishmaniasis are associated with lkaloids, acetogenins, sterols, and terpenes, secondary metabolites found in various parts of these plants.[38]

1- Annona glauca Schumach. & Thonn

Annona glauca (dugor mer in Wolof) is a small shrub or bush that grows to a maximum height of 1.5 m. It is found in tropical and subtropical regions of Asia, South America, and Africa (Senegal, Guinea, Ghana, Togo, Benin). The roots of the species have antiseptic and anti-infectious properties, which is why it is used to treat skin diseases, venereal diseases, and malaria.[39] Studies conducted on dichloromethane extracts from *A. glauca* seeds on promastigotes of *L. braziliensis*, *L. donovani*, and *L. amazonensis* reported significant IC100 concentrations of 25 µg/mL of the parasites after 48 hours. Various acetogenins were isolated and tested under the same conditions on *Leishmania* strains: Glaucanisin, Rolliniastatin, Squamocin, Glaucafilin, Annonacin A, Annonacin, and Goniothalamicin, with Annonacin and Goniothalamicin proving to be more active with $_{IC100}$ values of 10 and 5 µg/mL, respectively, and $_{IC100}$ values of 25 µg/mL for the others.[40][31]

2- Annona muricata (Linn)

Annona muricata (ser, nôm in Wolof), commonly known as soursop, is an evergreen, upright fruit tree that can grow to a height of 5 to 6 meters and is native to tropical America. The species has a variety of uses in traditional medicine. An infusion made from its leaves is used as a hypnotic, expectorant, and fever reducer.[29] Hexane and methanol extracts from the stem and ethyl acetate extracts from the pericarp, leaves, and stem of the species have been found to be active with IC50 ≤ 100 µg/mL. Acetogenins isolated from extracts of *A. muricata* have shown more significant antileishmanial activity against promastigotes of *L. donovani*, *L. mexicana*, and *L. major*. Annonacinone isolated from *A. muricata* showed high activity against promastigotes of these Leishmania species with respective $_{IC50}$ values of 6.72, 7.66, and 8.00 µg/mL for *L. major*, *L. donovani*, and *L. mexicana*, and values of 37.6 µg/mL and 13.5 µg/mL on promastigotes and amastigotes of *L. chagasi*, respectively.[41][36]

3- Annona senegalensis (Pers.)

A shrub 2-6m tall, *Annona senegalensis (Pers.)* (dugor in Wolof) is mainly found in savannah and parts of tropical rainforest regions. It is found in Senegal, Nigeria, Cape Verde, Sudan, and South Africa. The species is used for various conditions in traditional medicine, treating a wide range of health problems, from malaria to gastrointestinal diseases.[42] *In vitro* studies conducted on hydroethanolic extracts (50:50) from the leaves and bark of *A. senegalensis* stems on *L. donovani* promastigotes yielded respective $_{IC50}$ values of 10.80 and 27.80 µg/mL

and respective selectivity indices of 25.32 (significant) and 4.60 (low).[37] The antileishmanial activities observed could be linked to the presence of alkaloids, tannins, flavonoids, saponins, terpenoids, and glycosides.

4- Annona squamosa L.

Native to tropical America, *Annona squamosa L.*, or custard apple, is cultivated in gardens around Dakar and Casamance. It is a small tree with branches that generally reaches 3 to 8 m in height. It is known for its insecticidal, antioxidant, anti-inflammatory, antiparasitic, and immunomodulatory properties.[29][43] These properties are associated with compounds present in the species such as alkaloids, triterpenes, phenolic compounds, peptides, acetogenins, essential oils, and fixed oils.[44] A benzylisoquinoline alkaloid, O-methylarmépavine, and an acetogenin C trihydroxy adjacent bistetrahydrofuran have been isolated from *A. squamosa* leaves. These compounds were tested against *L. chagasi* and respective $_{IC50}$ values of 23.3 and 26.4 µg/mL were obtained for promastigotes and $_{IC50}$ values of 25.4 and 25.3 µg/mL for amastigotes.[41]

3.3 The Apocynaceae family

This family of latex-producing plants is one of the largest and most important families of angiosperms, many of whose species have various medicinal properties. It is rare in temperate zones and abundant in intertropical environments. In Senegal, 15 genera of this family, including tree vines and shrubs, are found.[29]

1- Mondia Whitei (Hook.f.) Skeels

Mondia whitei (Hook.f.) is a popular medicinal plant endemic to Africa. Since ancient times, it has been used to treat various diseases such as anorexia, bilharzia, malaria, and skin diseases. Studies have confirmed its antimicrobial, anti-inflammatory, and vermifuge properties, as well as its aphrodisiac efficacy.[45][32] A study evaluating its antileishmanial activity against *L. donovani* promastigotes using its roots yielded a high $_{IC50}$ of 31.0 µg/mL.[37]

3.4 The Asclepiadaceae family

This family includes twining or climbing latex-producing plants, many of which are found in the Sahel and others in the Guinean and Sudanian savannas. Several pharmacological studies have been conducted on these plants, which have led to numerous medicinal applications. In Senegal, there are about twenty genera.

1- Calotropis procera (Aiton)

Calotropis procera, known as faftan in Senegal, is a plant found throughout the world (growing mainly in dry and semi-arid climates), native to Africa, with a milky sap.[46] It is renowned for its traditional therapeutic uses in the treatment of infectious diseases, skin and dermal conditions (infections, leprosy, wounds), malaria, fever, and even tumors.[47][46] Recently, it has been reported that extracts from *C. procera* exhibit anticancer, antidiabetic, antioxidant, antimalarial, and antimicrobial properties.[48][46][47] Extracts obtained from the leaves and stems of *C. procera* have been tested on promastigote strains of *L. major* in Morocco.[49] The methanolic extract of *C. procera* leaves significantly reduced the proliferation of *L. major* promastigotes with $_{IC50}$ values of 377.28 and 222.44 µg/mL for 24 and 72 h, respectively ($p < 0.01$).[46]

3.5 The Asteraceae family

The Asteraceae are the largest family in the world in terms of number of genera, species, and distribution. This diversity of species is the reason for their various pharmacological uses. In Senegal, more than fifty genera are distributed across the Sahelian, Guinean, and Sudanian climatic regions.

1- Acanthospermum hispidum DC.

An annual plant native to tropical America, *Acanthospermum hispidum (ndégétit or dagiganar* in Wolof*)* is found throughout Senegal except in the Guinean forest[29] and is widely used in traditional medicine. Its antimicrobial, anthelmintic, antitrypanosomal, and antileishmanial properties have been described in the literature.[50]. The whole plant of *A. hispidum* was tested on *L. donovani* promastigotes and an $_{IC50}$ of 32.1 µg/mL was obtained.[37] Two sesquiterpene lactones isolated from the aerial parts of *A. hispidum*: (15-acetoxy-8-[(2-methylbutyryloxy)]14-oxo-4,5-cis-acanthospermolide) (A) and (9-acetoxy-15-hydroxy-8-(2-methylbutyryloxy) -14-oxo4,5-trans-acanthospermolide) (B) showed interesting antiparasitic activity against *L. mexicana* with respective $_{IC50}$ values of 0.94 and 2.54 µM.[51]

3.6 The Bignoniaceae family

The Bignoniaceae family, comprising approximately 110 genera and 650 species, is a family of flowering plants, a number of which grow in North America and East Asia. Bignoniaceae plants are important for their reported bioactive constituents and diverse pharmacological activities. The Bignoniaceae are represented by four tree genera found in Senegal: *Stereospermum, Kigelia, Newbouldia, and Spathodea.*

1- Kigella africana (Lam.)

Kigella africana (synonym: *Kigelia pinnata*), known as dabolé or dabale, is widely distributed in South, Central, and West Africa. The plant can grow up to 20 m tall. In Senegal, it is mainly found in the Casamance maritime region and in coastal wetlands.[29] The plant is traditionally used to treat several diseases such as parasitic infestations, malaria, diabetes, and skin cancers.[52] Several families of molecules have been isolated from the species, including diterpenes, triterpenes, quinones, sterols, fatty acids, iridoids, and esters.[53] Hexane, dichloromethane, ethyl acetate, methanol, and aqueous extracts from the bark of *K. africana* yielded $_{IC50}$ values of 134 µg/mL *in vitro* on *L. major* promastigotes and $_{IC50}$ values of 148.5 (µg/mL) on *L. major* amastigotes over a 24-hour period *in vivo* using BALB/c mice.[54]

3.7 The Caricaceae family

The Caricaceae are a small family native to tropical America with 35 species currently divided into six genera and a disjointed distribution between Africa and the Neotropics.

1- Carica papaya L.

Also known as pawpaw, *Carica papaya* has been cultivated in most tropical countries. The leaves, fruit, seeds, flowers, and parts of the roots of the species have been documented for their nutritional and medicinal benefits.[55] Research studies have demonstrated the antileishmanial activity of the hydroethanolic extract of *Carica papaya* seeds with an IC50 of 1mg/mL.[37]

3.8 The Celastraceae family

This family is found in all regions of the world. The family comprises approximately 88 genera and 1,300 species of plants. These plants have been valued since ancient times because their extracts have useful medicinal properties. In Senegal, four genera are present: *Maytenus, Hippocratea, Reissantia,* and *Salacia*.

1- Maytenus senegalensis (Lam.)

Maytenus senegalensis is a thorny shrub that grows to a height of 8 m in the Sahel and the wooded savannah of West Africa, on all types of soil. The species is used to treat infectious diseases and has proven antibacterial and anti-inflammatory properties. Its main compounds are essential oils (terpineol, geraniol, linalool), alkaloids (ephedrine, norephedrine), mucilage, sterols, phenolic acids, flavonoids, anthocyanins, and tannins.[56] An *in vitro* study conducted on *L. donovani* promastigotes with ethanolic extract from the root bark of *M. senegalensis* revealed a $_{IC50}$ of 16.5 µg/mL.[57]

3.9 The Combretaceae family

This family is divided into approximately 20 genera with 600 species. The largest genera are *Combretum* and *Terminalia*, with approximately 370 and 200 species, respectively. Members of the Combretaceae are found mainly in tropical and subtropical regions. The Combretaceae family includes a wide range of tannins, flavonoids, terpenoids, and stilbenes.

1- Anogeissus leiocarpus Guill. & Perr

Anogeissus leiocarpus Guill. & Perr. (Synonym: *Anogeissus schimperi Hochst.*, gej in Wolof*)* is a woody species commonly found in the forest savannas of West Africa. Parts of the plant (leaves, stems, bark, and roots) are used in traditional medicine to treat many diseases such as malaria, African trypanosomiasis, cancer, diabetes, monkeypox, and yellow fever.[58][59] The results of the study conducted on the crude ethyl acetate extract of *A. leiocarpus* showed antileishmanial activity *in vitro* with an $_{IC50}$ of 25 µg/ml on *L. donovani*. Fractionation of this crude extract by a series of column chromatography, using silica and Sephadex LH-20 successively as stationary phases, led to the isolation and identification of eight flavonoids: Catechin (1), 4H-1-benzopyran-4-one, 7-[(6-deoxy-α-L-mannopyranosyl) oxy] -5-hydroxy-2-(4-hydroxy-3-methoxyphenyl) (2), Quercetin (3), Isoquercetin (4), Rutin (5), Vitexin (6), Kaempferol (7), and Procyanidin B2 (8). Rutin proved to be the most active with an $_{IC50}$ of 1.6 µM. Moderate activity was observed with isoquercetin (IC50=64.3 µM), procyanidin (IC50=34.0 µM) and kaempferol (IC50=69.2 µM). The remaining three compounds are inactive.[59]

2- Combretum comosum G. Don

Combretum comosum is a climbing shrub or large vine found from Senegal to southern Sudan, and southward to Uganda and Angola, with several pharmacological properties. The

leaves are applied to burns and skin infections; they are taken as a decoction as a purgative.[60] The methanolic extract of the plant's leaves tested on *L. infantum* gave an IC50 greater than 100 µg/mL.[31]

3- Guiera senegalensis J.F. Gmel.

Guiera senegalensis is widely used in traditional African medicine, particularly in the Sahel region, to treat coughs, gastrointestinal disorders, and neurological conditions such as Alzheimer's disease. Previous studies have reported antioxidant, neuroprotective, and antibacterial effects attributed to compounds such as flavonoids, alkaloids, and galloylquinic acid derivatives.[61] The hexane extract of *G. senegalensis* leaves showed promising antileishmanial activity against *Leishmania major*, with an IC_{50} of 16.69 ± 0.3 µg/mL. The ethyl acetate fraction showed moderate activity (IC_{50} = 89.63 ± 0.6 µg/mL)[62], while the crude methanolic extract showed a significant viability percentage of 0.4% on *L. mexicana Mexicana* at 100µg/mL.[63]

4- Terminalia avicennioides Guill. & Perr.

This plant is a yellowish-brown hardwood commonly found in the savanna region of West Africa. It has been reported to have been used traditionally to treat various diseases in animals and humans, such as tuberculosis, cough, and diabetes mellitus.[64]. *Abda Ba et al.* tested methanolic extracts from the leaves, roots, and root bark of the species on *L. mexicana mexicana* promastigotes at two concentrations, 50 and 100µg/mL. Viability percentages of 4.9, 3.0, and 3.4% were obtained for the leaves, roots, and root bark, respectively. The hexanoic and dichloromethane fractions of the crude methanolic extract showed moderate antileishmanial activities with IC_{50} values of 19.53 and 20.74 µg/mL, respectively.[63]

3.10 The Convulvulaceae family

This family comprises approximately 57 genera and 1,600 species, which are mainly twining herbs found in warm regions around the world. Plants in this family are of considerable economic and culinary importance. Twelve genera are represented in Senegal.

1- Calycobolus sp

The species are distributed from tropical South America and West Africa to Angola. A CI50 of 32.00 µg/mL was obtained in a study conducted on the aqueous extract of the bark of the stems of the species tested on *L. infantum*.[31]

3.11 The Cucurbitaceae family

The Cucurbitaceae family includes a wide range of vegetables and fruits that are very important to the national and local economies. Plants in this family are rich in terpenes, glycosides, alkaloids, saponins, tannins, and carotenoids, which are responsible for their therapeutic effects.[65]

1- Citrullus colocynthis (L.)

An annual trailing plant growing to a height of 4 to 5 m, it is cultivated for its fruit pulp and edible seeds throughout Senegal, especially in the Sahel region.[29] The fruits of *C. colocynthis* have been widely used in traditional medicine for their medicinal properties. In a study conducted by *Baloch et al.*, the crude methanolic extract of the fruits and its fractions (chloroform, acetone, and aqueous) were tested against *L. major* parasites. The results showed significant antileishmanial activity with $_{IC50}$ values of 11.99 µg/mL for the methanol extract and 18.60 µg/mL for the chloroform fraction. The aqueous fraction was less active with an $_{IC50}$ greater than 100 µg/mL.[66]

3.12 The Dioscoreaceae family

This family from tropical and warm temperate regions is represented in Senegal by the genus *Dioscorea* with six species.[29] *Dioscorea* species have various pharmacological activities such as anti-inflammatory, antimicrobial, anticancer, antidiabetic, and estrogenic effects. Compounds such as diosgenin, phenolic compounds, flavonoids, and terpenes are isolated from different organs of the species.[67]

1- Dioscorea preussii Pax

Native to tropical Africa, this is a tuberous climbing geophyte that grows mainly in the tropical dry season biome. *D. preussii* is thought to have cytotoxic, antileishmanial, and antifungal activities *in vitro***.** The methanolic extract of the leaves tested on *L. infantum* gave an $_{IC50}$ of 68.6 µg/mL *in vitro*.[31]

3.12 The Euphorbiaceae family

This tropical and subtropical family consists of several medicinal or toxic species, as well as food and industrial species. In Senegal, there are 25 genera represented throughout the country, from the Senegal River valley to Casamance.

1- Anthostema senegalensis A. Juss.

*Anthostema senegalensis (*Kindin in Wolof*)* is an 8-10 m tall latex tree with a straight trunk, but more often a 4-5 m tall shrub. It is found in the humid and marshy areas of Casamance and the Sudanese region and is found in the Niayes around Dakar.[29] The leaves of this species are traditionally used as an anti-inflammatory. The methanolic extract of the leaves has shown significant anti-leishmanial activity with an IC50 of 9.8 µg/mL on *L. donovani* promastigotes.[68]

2- Ricinus communis L.

Ricinus communis (Kerhom in Wolof) is generally a shrub 2 to 3 meters tall, found in most villages in Senegal. The seeds, roots, flowers, bark, and leaves of the castor oil plant are used to treat many ailments such as infections, inflammation, and leprosy, and are used as an antiseptic for wounds and injuries and for their emetic and purgative effects.[29] An *in vivo study* demonstrated the leishmanicidal effect of ethyl acetate extract of *R. communis* on *L. infantum* amastigotes. *Jumba et al. (2015)* reported an antileishmanial action of the methanolic extract of *R. communis* leaves on *L. major in vivo* and *in vitro* with respective $_{IC50}$ values of 16.5 and 25.5 µg/mL.[69] Hydroethanolic extracts (70:30) from the leaves, roots, bark, flowers, and fruits of the species can inhibit the growth of *L. major* promastigotes at a concentration of 100 mg/mL.[70][71]

3.14 The Fabaceae family

This family is widely represented across the globe, particularly in warm regions. It includes species used for food, fodder, and medicinal purposes. In Senegal, there are 57 genera spread across the Sudanese, Sahelian, and Guinean zones.

1- Abrus precatorius L.

Abrus precatorius (sébu tubab in Wolof) is a perennial twining vine 3-4 m tall, found throughout Senegal. In traditional medicine, the seeds are used as an external remedy for abscesses and inflammation in Senegal (Walo) and for skin diseases and ulcers in India.[29] The leaves, roots, and seeds are used for their anti-helminthic, antidiarrheal, and antiemetic properties and to inhibit intestinal motility.[72] A study by *Okoro et al.* (2020) reported significant antileishmanial activities of the methanol, hexane, and ethyl acetate fractions of *A. precatorius* roots with $_{IC50}$ values of 22.20 ± 0.540 µg/mL, 19.35 ± 0.670 µg/mL and 6.32 ± 0.001 µg/mL, respectively, against *L. major*. The ethyl acetate fraction, which was the most

active fraction, was subjected to column chromatography, and two isoflavanquinones were isolated: abruquinone A and abruquinone B. The compounds showed significant antileishmanial activity ($p < 0.05$) against *L. major* (IC50 6.35 ± 0.005 µg/mL and 6.32 ± 0.008 µg/mL, respectively) and *L. tropica* (IC50 6.29 ± 0.015 µg/mL and 6.31 ± 0.005 µg/mL, respectively).[73] *In vitro* tests also demonstrated the antileishmanial activities of the hexane, chloroform, methanol, and ethyl acetate fractions of the leaves on *L. donovani* with respective $_{LC50}$ values of 15.7, 24.1, 42.3, and 47.4 µg/mL.[72]

2- Afzelia africana Sm. ex Pers.

This plant is commonly known as African mahogany and thrives in tropical regions of Africa. Different parts of the plant have been used in traditional medicine as an analgesic, for the treatment of malaria, as a diuretic, and to treat paralysis and lumbago.[74] The hydroethanolic extract of the stem bark has shown leishmanicidal activity with an IC50 of 77.1 µg/mL on *L. donovani* promastigotes.[37]

3- Cassia alata L.

Cassia alata (mbata in Wolof) is a 2-3 m shrub native to tropical America and abundant in Casamance. It is a medicinal plant whose various parts are used to treat a range of conditions: abdominal pain, skin diseases, and acts as an anti-inflammatory and antifungal agent.[75] *In vitro* testing of the hydroethanolic extract of the leaves on *L. donovani* promastigotes gave an $_{IC50}$ of 10.10 µg/mL.[76]

4- Cassia sieberiana DC.

Cassia sieberiana is a perennial tree native to Africa and is used in traditional medicine to treat fever, diarrhea, leprosy, dropsy, bilharzia, and abdominal pain.[77] Methanolic and hydroethanolic (50:50) extracts from *C. sieberiana* leaves tested on *L. donovani* showed significant antileishmanial activity with $_{IC50}$ values slightly above 40 µg/mL an grow up to 24 m tall and 7 m in circumference. In addition to its nutritional value, tamarind is used in traditional African and Asian medicine to treat many diseases such as helminth infections, wound healing, malaria, fever, inflammation, and eye diseases.[79] The hydroethanolic extract (50:50) of *T. indica* leaves has shown antileishmanial activity *in vitro* on *L. donovani* with an $_{IC50}$ of 58.12 µg/mL.[80][76]

3.15 **The Gentianaceae family**

lants in this family are found throughout the world. There are 939 to 968 species widely used

in traditional medicine for their antibacterial, antioxidant, anticancer, and antiviral effects.

1- Anthocleista nobilis G. Don

Several parts of the plant are used to treat various diseases in humans and animals, such as malaria, diabetes, diarrhea (in dogs), etc. Hydroethanolic extracts from the root bark and leaves of *A. nobilis* have shown antileishmanial activity against *L. major* with an IC50 of 53.95±0.01 µg/mL[81] and against *L. donovani* with an $_{IC50}$ of 41.5 µg/mL *in vitro.*[76]

3.16 The Lamiaceae family

Lamiaceae is the sixth largest family of angiosperms with more than 245 genera and 7,886 pecies, distributed throughout the world. It includes many economically and medicinally important species due to the wide variety of secondary compounds they contain, particularly essential oils.

1- Ocimum gratissimum L.

Ocimum gratissimum L. is a widespread and commercially viable perennial herbaceous plant with a very strong aromatic odor. It is found in Africa, Asia, and South America. Scientific reports have shown that *O. gratissimum* possesses a wide range of bioactive compounds such as flavonoids and polyphenols, as well as essential oils with several beneficial effects.[82] The aqueous extract of *O. gratissimum* leaves gave an IC50 of 20.32 µg/mL *in vitro* on *L. infantum.*[83]

3.17 The Liliaceae family

The Liliaceae are an important family with around 705 species divided into 15 genera with varied biological properties. They are found in warm and temperate regions around the world. Fourteen genera exist in Senegal.

1- Allium sativum L.

Allium sativum L. (garlic) is an aromatic herb and spice derived from the bulb, one of the most sought-after plants, used as a culinary ingredient and in ethnomedicine for various diseases around the world. Previous studies have highlighted the antioxidant, hypoglycemic, anti-inflammatory, anticancer, antimicrobial, and hepatoprotective properties of the species.[84] Several studies have confirmed the antileishmanial effect of *A. sativum*. Aqueous and methanolic extracts of *A. sativum* tested on *L. tropica* promastigotes showed leishmanicidal actions with respective $_{IC50}$ values of 19.2 and 12.3 µg/mL.[13] Similarly, a

recent study highlighted the anti-Leishmania action of *A. sativum* essential oil on promastigotes (IC50=1.76 µg/mL), axenic amastigotes (IC50=3.46 µg/mL) and intracellular amastigotes (IC50=3.77 µg/mL) of *L. amazonensis.*[85]

3.18 The Malvaceae family

This family comprises approximately 304 species, most of which are trees distributed throughout different parts of the globe and have significant medicinal and economic value.

1- Ceiba pentandra L.

The species *C. pentandra*, measuring between 30 and 50 m in height, has spread from the Neotropics to West Africa, where populations grow wild along the coast from Senegal to Angola. Several studies have reported the biological properties of the species, such as antidiabetic, antimicrobial, and antiviral properties.[86] The hydroethanolic extract of the stem bark has shown antileishmanial activity on *L. donovani* promastigotes with an IC50 of µg/mL.[76]

3.19 The Marantaceae family

The Marantaceae family comprises approximately 31 genera and 550 species. Members of this family are natie to tropical rainforests and swamps, particularly in America, but also in Africa and Asia. Several species are cultivated as ornamental plants or as a source of edible starch.

1- Thalia geniculata L.

Thalia geniculata is an African medicinal shrub traditionally used in Benin to treat malaria and other parasitic diseases. There is little ethnobotanical information and almost no chemical information available for this species.[87] However, studies have revealed the *in vitro* antiparasitic activity of the ethanolic extract of the species' roots on *L. braziliensis* with an IC50 of 17.4 µg/mL.[88]

3.20 The Meliaceae family

An economically important family due to its precious woods, Meliaceae are found in all tropical regions and five genera are found in Senegal: *Docedrela, Khaya, Carapa, Trichillia,* and *Pseudocedrela*.

1- Azadirachta indica A. Juss.

Azadirachta indica, commonly known as neem or nim in Wolof, has long been recognized for its medicinal properties. It grows in tropical and subtropical regions around the world. The plant has antioxidant, antidiabetic, anti-inflammatory, antimicrobial, and immunomodulatory properties.[89] *In vitro* and *in vivo* studies of methanolic extracts from the leaves conducted on promastigotes and amastigotes of *L. major* showed IC50 values of 10.1 and 11.5 µg/mL, respectively.[90]

3.21 The Moraceae family

The Moraceae family comprises 50 genera and 1,400 species in tropical and subtropical regions around the world. Plants in this family have been reported to possess various properties, such as antibacterial, anti-inflammatory, and antidiabetic properties, and certain species have high economic value.

1- Ficus capensis Thunb.

Ficus capensis Thunb, also known as *Ficus sur Forssk*, is mainly found in tropical Africa and can grow to a height of 4 to 9 m. Its various parts appear to have antimicrobial, anti-inflammatory, and antioxidant properties, which have been linked to the presence of phytochemicals such as flavonoids, tannins, phenolic compounds, and anthocyanins.[91] The hydroethanolic extract of the species' stem bark was tested on *L. donovani* and an IC50 of 37 µg/mL was obtained.[92]

3.22 The Ochnaceae family

The Ochnaceae comprise 27 genera and approximately 495 species of tropical trees and shrubs, with a few genera of herbs. Many species are native to Brazil. The most important genus is Ouratea (including Gomphia), with approximately 200 species. The tropical African and Asian genus *Ochna* has nearly 90 species.

1- Lophira lanceolata Thiegh. Ex Keay

The plant is known as "red oak or false shea" and is a species of tree that can grow up to 12 m tall, widely distributed in the wooded savannas of tropical Africa. *L. lanceolata* is known for its various uses in traditional medicine. Studies on the pharmacological activity of this plant have revealed that it has antipyretic activity, chronic wound healing potential, antimicrobial activities, and antidiarrheal and antiplasmodial effects.[93] The hydroethanolic extract of the roots has shown antileishmanial activity on *L. donovani* with an $_{IC50}$ of 66 µg/mL.[92]

3.23 The Olacaceae family

The Oleaceae are a family of dicotyledonous flowering plants, widely distributed in temperate and tropical regions, comprising 5 genera with approximately 688 species. The family has significant economic, horticultural, and medicinal importance due to its chemical constituents.

1- Ximenia americana L.

This medicinal plant is a bushy, thorny shrub, 4 to 5 m tall with an open crown, traditionally used for the treatment of malaria, fever, leprosy ulcers, and mixed skin infections.[94] The hydroethanolic extract of *X. americana* stems is active against *L. donovani*, and a $_{IC50}$ of 36.1 µg/mL was reported in a recent study.[92]

3.24 The Plantaginaceae family

The plantain family is a family of flowering plants comprising approximately 94 genera and around 1,900 species, the largest genus being *Veronica Linn.*, which includes more than 450 species. Today, Plantaginaceae is a diverse and cosmopolitan family, found mainly in temperate zones. The plants are generally herbs and shrubs, and the boundaries of the family are difficult to establish.

1- Scoparia dulcis L.

Scoparia dulcis L. is a widely used tropical herb in folk medicine as an analgesic and antipyretic, for gastric disorders, bronchitis, diabetes, hypertension, hemorrhoids, and insect bites. Chemical analysis of *S. dulcis* has identified various components, including flavonoids, triterpenoids, steroids, and phenolic compounds, which may demonstrate its defined pharmacological effects.[95] The species has antileishmanial properties, as confirmed by an *in vitro* study of ethanolic extracts from its aerial parts on *L. amazonensis*. A $_{CI50}$ of 23.9 µg/mL was obtained.[96]

3.25 The Rubiaceae family

The Rubiaceae family has a cosmopolitan distribution, mainly concentrated in the tropics. It comprises approximately 637 genera and 13,000 species and represents one of the most important families of plants in terms of economic, ornamental, and medicinal value among angiosperms. This family exhibits a wide diversity of substances such as iridoids, indole alkaloids, anthraquinones, terpenes (diterpenes and triterpenes), flavonoids, and other phenolic derivatives, with an emphasis on the production of bioactive alkaloids.[97]

1- Morelia senegalensis A.Rich. ex DC

Morelia senegalensis is an often-bushy shrub that can reach 3 to 12 m in height. It is found in marginal forests and on the banks of savanna rivers throughout Senegal, northern and southern Nigeria, and as far as Congo (Brazzaville) and Sudan. The antileishmanial activity of the species has been proven on *L. infantum*. Dichloromethane and methanol extracts from the bark of the stems and leaves gave IC50 values of 34.2 µg/mL and 53.4 µg/mL, respectively.[98]

3.26 The Verbenaceae family

Verbenaceae are trees or herbs that produce essential oils and are widely distributed in warm regions around the world. The family comprises 955 species and 33 genera. In Senegal, one-eighth of the genera are found.

1- Lantana camara L.

Lantana camara, commonly known in Senegal as "duté gabi," is one of the most toxic plants with a wide and diverse geographical distribution. Various parts of the plant, including its leaves, roots, and flowers, have traditionally been used to treat conditions such as malaria, tuberculosis, and gastrointestinal disorders. Previous studies have shown the antileishmanial capacity of ethanolic extracts from *L. camara* leaves with an IC50 of 12.20 µg/mL on promastigotes and 7.29 µg/mL on amastigotes of *L. amazonensis* with a good selectivity index of 30.64.[99] Another study, also conducted on *L. amazonensis*, demonstrated the antileishmanial activity of dichloromethane extracts from the leaves and bark, with $_{IC50}$ values of 11.7 µg/mL for promastigotes and 21.8 µg/mL for amastigotes.[100]

Table 1: List of 39 medicinal plants from Senegalese flora with proven antileishmanial activity.

No.	Plant species	Parasite	Stage	Parts used	Extract/Compound	IC_{50} (µg/mL)	Ref.
1	*Abrusprecatorius*	***L. donovani***	*Promastigote*	**Leaves**	Hexane/CHCl3/MeOH/AcOEt	**15.7/24.1/42.3/47.4**	[72]
		L. major	*Promastigote*	**Roots**	Hexane/MeOH/AcOEt	**19.35/22.20/6.32**	[73]
		L. major	*Promastigote*	**Roots**	Abruquinon A/Abruquinone B	**6.35/6.32**	[73]
		L. tropica	*Promastigote*	**Roots**	Abruquinon A/ Abruquinone B	**6.29/6.31**	[73]
	Acanthospermum hispidum	***L. donovani***	*Promastigote*	**Whole plant**	Lactone B	**2.54**	[25]
2		***L. donovani***	*Promastigote*	**Whole plant**	Lactone A	**0.94**	[37]
3	*Afzelia africana*	***L. donovani***	*Promastigote*	**Stem barks**	Ethanol: Water (50:50)	**77.1**	[37]
4	*Allium sativum*	***L. tropica***	*Promastigote*	**Whole plant**	Aqueous / Ethanol	**19.2 / 12.3**	[85]
5	*Annona glauca*	***L. braziliensis***	*Promastigote*	**Seeds**	Dichloromethane (DCM)	**12.5**	[40][31]
6	*Annona muricata*	***L. major***	*Promastigote*	**Leaves/barks**	Annonacinone	**6.72**	[41][36]
		L. donovani	*Promastigote*	**Leaves/barks**	Annonacinone	**7.66**	41][36]
		L. mexicana	*Promastigote*	**Leaves/barks**	Annonacinone	**8**	[41][36]
	Annona senegalensis	***L. donovani***	*Promastigote*	**Stem barks**	Ethanol: Water (50:50)	**27.8**	[37]
7		***L. donovani***	*Promastigote*	**Leaves**	Ethanol: Water (50:50)	**10.8**	[37
	Annona squamosa	***L. chagasi***	*Promastigote*	**Leaves**	O-methylarmempavine	**23.3**	[41]
8		***L. chagasi***	*Promastigote*	**Leaves**	C trihydroxybistétrahydrofuran	**26.4**	[41]
9	*Anogeissus leiocarpus*	***L. donovani***	*Promastigote*	**-**	AcOEt	**25**	[59]
10	*Anthocleista nobilis*	***L. donovani***	*Promastigote*	**Leaves**	Ethanol: Water (50:50)	**41.5**	[36]
11	*Anthostema senegalensis*	***L. donovani***	*Promastigote*	**Leaves**	MeOH	**9.8**	[68]
12	*Azadirachta indica*	***L. major***	*Promastigote*	**Leaves**	MeOH	**10.1**	[90]
		L. major	*Promastigote*	**Leaves**	MeOH	**11.5**	[90]
13	*Calotropis procera*	***L. major***	*Promastigote*	**Leaves**	MeOH	**222.44**	[46]
14	*Calycobolus sp*	***L. infantum***	*Promastigote*	**Stem barks**	Aqueous	**32**	[31]
15	*Carica papaya*	**-**	*Promastigote*	**Seeds**	Ethanol: Water	**>500**	[37]

16	*Cassia alata*	***L. donovani***	*Promastigote*	**Leaves**	Ethanol: Water	**10.1**	[76]
17	*Cassia sieberiana*	***L. donovani***	*Promastigote*	**Leaves**	Ethanol: Water	**62.9**	[36]
18	*Ceiba pentandra*	***L. donovani***	*Promastigote*	**Stem barks**	Ethanol: Water	**31.1**	[36]
19	*Citrullus colocynthis*	***L. major***	*Promastigote*	**Fruits**	FCHCl3	**18.6**	[66]
		L. major	*Promastigote*	**Fruits**	MEOH	**11.99**	[66]
20	*Combretum comosum*	***L. infantum***	*Promastigote*	**Leaves**	MeOH	**>100**	[31]
21	*Dioscorea preussii*	***L. infantum***	*Promastigote*	**Leaves**	MeOH	**68.6**	[31]
22	*Ficus capensis*	***L. donovani***	*Promastigote*	**Stem barks**	Ethanol: Water	**37**	[25]
23	*Guiera senegalensis*	***L. major***	*Promastigote*	**Leaves**	Hexane	**16.69**	[62]
		L. major	*Promastigote*	**Leaves**	FAcOEt	**89.63**	[62]
24	*Kigella africana*	***L. major***	*Promastigote*	**Barks**	Hexane/DCM/AcOEt/MEOH	**134**	[54
		L. major	*Amastigote*	**Barks**	Hexane/DCM/AcOEt/MEOH	**148.5**	[54]
25	*Lantana camara*	***L.amazonensis***	*Promastigote*	**Leaves**	Ethanol	**12.2**	[99]
		L. amazonensis	*Amastigote*	**Leaves**	Ethanol	**7.29**	[99]
		L. amazonensis	*Promastigote*	**Leaves/barks**	DCM	**11.7**	[100]
		L. amazonensis	*Amastigote*	**Leaves/barks**	DCM	**21.8**	[100]
26	*Lophira lanceolata*	***L. donovani***	*Promastigote*	**Roots**	Ethanol: Water	**66**	[25]
27	*Mangifera indica*	***L. donovani***	*Promastigote*	**Leaves**	MeOH	**2.74**	[28]
28	*Maytenus senegalensis*	***L. donovani***	*Promastigote*	**Root Bark**	Ethanol	**16.5**	[57]
29	*Mondia Whitei*	***L. donovani***	*Promastigote*	**Roots**	-	**31**	[3]
30	*Morelia senegalensis*	***L. infantum***	*Promastigote*	**Stem barks**	DCM	**34.2**	[98]
31	*Ocimum gratissimum*	***L. infantum***	*Promastigote*	**Leaves**	Aqueous	**20.32**	[83]
32	*Pseudospondias microcarpa*	***L. donovani***	*Promastigote*	**Stem barks**	Ethanol	**29.9**	31][32]
33	*Ricinus communis*	***L. major***	*Promastigote*	**Leaves**	MeOH	**25.5**	[31][32]

		L. major	*Amastigote*	**Leaves**	MeOH	**16.5**	[69]
34	*Scoparia dulcis*	***L.amazonensis***	*Promastigote*	**Aerial part**	Ethanol	**23.9**	[101]
35	*Spondias mombin*	***L. donovani***	*Promastigote*	**Leaves**	Ethanol: Water	**81.5**	[36][37]
36	*Tamarindus indica*	***L. donovani***	*Promastigote*	**Leaves**	Ethanol: Water	**58.12**	[80][36]
37	*Terminalia avicennioides*	***L. mexicana***	*Promastigote*	**Whole plant**	Hexane/DCM	**19.53/20.74**	[63]
38	*Thalia geniculata*	***L. braziliensis***	*Promastigote*	**Roots**	Ethanol	**17.4**	[101]
39	*Ximenia americana*	***L. donovani***	*Promastigote*	**Stem/Twigs**	Ethanol: Water	**36.1**	[25]

4 MECHANISMS OF ACTION OF NATURAL MOLECULES AGAINST LEISHMANIAS

The anti-Leishmania activities of species could be attributed to their chemical compositions. Indeed, active plant molecules such as phenols, flavonoids, terpenes, alkaloids, etc. are recognized as being effective against parasites of the *Leishmania* genus. These compounds act against Leishmania through various mechanisms, including the disintegration of cytoplasmic membranes, disruption of electron flow, active transport of crucial substances, coagulation of cellular contents, and destabilization of proton motive forces.[102]

- Terpenes can induce apoptosis by penetrating the lipid bilayer of the Leishmania cell membrane, thereby causing changes in the integrity of the cell structure and the mitochondrial membrane.[103]

- Flavonoids are common constituents of medicinal plants with particularly antioxidant and anticancer biological effects. Studies have reported the leishmanicidal action of flavonoids through various mechanisms, such as the production of reactive oxygen species causing mitochondrial changes and cell death (e.g., quercetin)[104] and/or through the inhibition of enzymes involved in Leishmania infections.[105]

- Quinones (examples: abruquinone A and abruquinone B) are highly active molecules whose radicals are capable of leading to the formation reactive oxygen species including O_2^-, H_2O_2, and hydroxyl radicals OH·, which could explain their leishmanicidal activity *in vitro*.[106]

- Many alkaloids have been described as having biological activity against Trypanosomatidae, such as *Leishmania spp*. For example, heterocyclic steroids (solamargine and solasonine) have induced different immunochemical pathways in macrophages and dendritic cells. In addition, the isoquinoline alkaloid (berberine) has leishmanicidal activity by reducing the viability of promastigotes and generating reactive oxygen species in these cells. It also increased mitochondrial superoxide levels and induced mitochondrial transmembrane potential depolarization.[107]

- Annonaceae acetogenins are natural bioactive compounds known to exhibit interesting biological activities, including cytotoxic, insecticidal, and antiprotozoal activities. revious studies on extracts containing acetogenins have described the leishmanicidal activities of

these compounds. The mechanism of action of acetogenins in Leishmania is unknown. Acetogenins are thought to be potent inhibitors of mitochondrial complex I, ubiquinone oxidoreductase, in mammalian cells, and most studies have been conducted using bovine heart mitochondrial complex I.[108][109]

The difference in results can be explained, on the one hand, by the difference in the chemical composition of the plants and, on the other hand, by the nature of the *Leishmania* strains used, the extraction methods, and the pharmacological tests used.

5. CONCLUSION AND OUTLOOK

The results reported here demonstrate the promising potential of medicinal plants as candidates for the treatment of leishmaniasis. Several extracts and fractions of these plants have shown significant leishmanicidal activity against different strains responsible for cutaneous and visceral leishmaniasis. Similarly, the compounds isolated from these extracts and/or plant fractions represent avenues for the development of antileishmanial drugs. However, the majority of experiments are performed *in vitro*, and further studies, particularly those related to cytotoxicity and antileishmanial activity *in vivo*, are needed to increase the number of phytomedicine candidates against leishmaniasis. For an order to promote and recognize preparations derived from natural resources, extracts and/or isolated compounds must first be tested in preclinical trials and then in randomized clinical trials.

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