Al-Mustaqbal Journal of Pharmaceutical and Medical Sciences

Volume 4 | Issue 1 Article 3

Ethnopharmacology, Phytochemistry, and Pharmacological Potential of *Philenoptera laxiflora*: An Emerging African Medicinal Plant for Drug Discovery

Albashir Tahir
Department of Pharmacology, Faculty of Basic Medical Sciences, Sa'adu Zungur University, Bauchi State, Nigeria, albashirtahir@sazu.edu.ng

ISSN: 2959-8974 – e-ISSN: 3006-5909

AL-MUSTAQBAL JOURNAL OF PHARM. & MED. SCIENCES 2026;4:14–25

REVIEW

Ethnopharmacology, Phytochemistry, and Pharmacological Potential of *Philenoptera laxiflora*: An Emerging African Medicinal Plant for Drug Discovery

Albashir Tahir

Department of Pharmacology, Faculty of Basic Medical Sciences, Sa'adu Zungur University, Bauchi State, Nigeria

ABSTRACT

Medicinal plants remain an important source of therapeutic agents and play a significant role in modern drug discovery. *Philenoptera laxiflora* (Fabaceae) is a tropical African plant widely used in traditional medicine, but the scientific evidence supporting its therapeutic potential remains fragmented. This review aims to comprehensively summarize the current knowledge on the ethnomedicinal uses, phytochemical composition, pharmacological activities, and toxicological profile of *P. laxiflora*, while highlighting research gaps and future directions for drug discovery. A comprehensive literature search was conducted using electronic scientific databases, including PubMed, Google Scholar, Scopus, Web of Science, and ScienceDirect. Relevant publications on the ethnobotany, phytochemistry, pharmacology, and toxicology of *P. laxiflora* were identified using targeted keywords such as "*Philenoptera laxiflora*", "*Lonchocarpus laxiflorus*", "ethnomedicine", "phytochemistry", "pharmacological activity", and "toxicity". Studies published in peer-reviewed journals, ethnobotanical reports, and related scientific sources were critically analyzed and synthesized. Ethnobotanical evidence indicates that various parts of *P. laxiflora* are traditionally used to manage numerous diseases, including diabetes, infections, parasitic diseases, liver disorders, and inflammatory conditions. Phytochemical investigations have identified diverse secondary metabolites, and experimental studies have demonstrated several activities, including antimicrobial, antihyperglycemic, cytotoxic, and antiparasitic effects. Toxicological evaluations suggest a relatively favorable safety profile, with acute and sub-chronic studies indicating low toxicity. *P. laxiflora* represents a promising yet underexplored medicinal plant with significant potential for natural product–based drug discovery. Further research focusing on bioactive compound isolation, mechanistic pharmacology, comprehensive toxicological evaluation, and clinical validation is necessary to realize its therapeutic potential fully.

Keywords: *Philenoptera laxiflora*, Ethnopharmacology, Phytochemistry, Pharmacological activity, Natural products

1. Introduction

Medicinal plants have historically served as an indispensable source of therapeutic agents and continue to play a central role in modern drug discovery and development. A significant proportion of currently used pharmaceuticals are either directly derived from natural products or structurally inspired by plant secondary metabolites [1]. Recent analyses confirm the enduring role of natural products in pharmaceuticals: among 520 USFDA-approved drugs from 1983–1994, about 39% were natural products or derivatives, rising to 60-8-0% for antibiotics and anticancer agents. From 1981–2014, of 1562 approved drugs, 4% were pure natural products, 21% derived, and 9% herbal mixtures [2]. Globally, about 35% of the ~$1.1 trillion medicine market stems from natural sources (25% plants, 13% microbes, 3% animals) [3]. Amid

Received 10 March 2026; revised 18 April 2026; accepted 19 April 2026.
Available online 15 April 2026

E-mail address: albashirtahir@sazu.edu.ng (A. Tahir).

https://doi.org/10.62846/3006-5909.1040

synthetic design challenges, natural products provide diverse scaffolds while advances in screening continue to bolster their importance in drug discovery for pandemics and chronic diseases [4].

Ethnopharmacology, the scientific study of traditional medicinal practices and the biological properties of natural remedies, provides a valuable framework for identifying promising plant species with therapeutic potential [5]. Traditional knowledge, passed down through generations, serves as a critical roadmap for discovering bioactive compounds and pharmacologically promising plants. Many medicinal plants first identified in traditional healing systems have been scientifically validated via phytochemical analysis and pharmacological testing, confirming their efficacy [6]. Integrating ethnobotanical insights with contemporary techniques like high-throughput screening and molecular docking has proven highly effective in pinpointing novel lead compounds, accelerating drug development while honoring indigenous wisdom [7].

The family Fabaceae represents one of the largest and most pharmacologically significant plant families, comprising more than 19,000 species distributed across diverse ecological regions worldwide. Members of this family are known to produce a wide array of bioactive secondary metabolites, including flavonoids, alkaloids, terpenoids, tannins, and phenolic compounds, many of which exhibit notable pharmacological properties such as antioxidant, antimicrobial, anti-inflammatory, and anticancer activities [8–10]. Consequently, several species within this family have attracted considerable attention in ethnopharmacological and phytochemical research. Among these, *Philenoptera laxiflora* (syn. *Lonchocarpus laxiflorus*) (Guill. & Perr.) Roberty is a tropical leguminous tree widely distributed in parts of sub-Saharan Africa. The species is commonly found in savannah woodlands and forest margins and has been used traditionally in various African ethnomedical systems [11]. Different parts of the plant, including the bark, leaves, and roots, have reportedly been employed in traditional medicine for the management of infections, inflammatory conditions, and other ailments. Ethnobotanical surveys have documented the use of the plant in traditional healing practices, highlighting its potential importance as a source of pharmacologically active compounds [11, 12].

Recent scientific investigations have begun to explore the phytochemical composition and biological activities of *P. laxiflora*. Preliminary studies indicate that extracts of the plant contain diverse classes of secondary metabolites, including phenolic compounds, flavonoids, and other bioactive constituents that may contribute to its medicinal properties [12]. Experimental pharmacological studies have reported antimicrobial, antioxidant, anti-inflammatory, and cytotoxic activities associated with different extracts of the plant. These findings provide preliminary scientific support for some of its traditional uses and suggest that the species may represent a promising source of bioactive molecules with therapeutic potential.

Despite these emerging pharmacological insights, the available information on *P. laxiflora* remains fragmented across ethnobotanical reports, phytochemical investigations, and pharmacological studies. To date, a comprehensive synthesis integrating the ethnomedicinal uses, phytochemical constituents, and pharmacological activities of this species remains limited. Such integration is essential for identifying research gaps, guiding future investigations, and evaluating the therapeutic potential of the plant within a broader pharmacological context, positioning the species as an underexplored candidate for future pharmacological and natural product research. Therefore, the present review aims to comprehensively summarize and critically analyze the existing literature on the ethnopharmacology, phytochemical composition, and pharmacological activities of *P. laxiflora*, and outline future research directions necessary for the development of novel pharmacological agents derived from this medicinal plant.

2. Methodology

This review was conducted as a narrative literature synthesis of published studies related to *Philenoptera laxiflora*. Relevant scientific articles were retrieved from major electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, and ScienceDirect. The literature search covered records from database inception to March 2026. The search strategy employed combinations of keywords such as “*Philenoptera laxiflora*”, “*Lonchocarpus laxiflorus*”, ethnomedicine, phytochemistry, pharmacological activity, toxicity, and natural products. Additional sources were identified from the reference lists of relevant publications and ethnobotanical reports. Only studies written in English and providing information on the botanical description, ethnomedicinal uses, phytochemical constituents, pharmacological activities, and toxicological evaluation of the plant were included. The retrieved literature was carefully screened, and relevant findings were systematically organized and synthesized to provide an integrated overview of the current scientific knowledge and research gaps related to *P. laxiflora*.

3. Botanical description

3.1. Taxonomic classification

Taxonomically, *P. laxiflora* belongs to the leguminous family Fabaceae, one of the largest and most ecologically and pharmacologically important plant families, comprising about 12 species distributed in Africa and Madagascar. Species of this genus were previously included in the genus *Lonchocarpus*, which is now regarded as largely restricted to tropical America [13]. The taxonomic classification is as follows:

- Kingdom: Plantae
- Clade: Angiosperms
- Clade: Eudicots
- Order: Fabales
- Family: Fabaceae
- Subfamily: Faboideae
- Genus: Philenoptera
- Species: *Philenoptera laxiflora* [11]

3.2. Synonyms and vernacular names

Like many African medicinal plants, *P. laxiflora* has been reported under different botanical synonyms in earlier taxonomic literature due to historical revisions in classification systems. These synonyms can occasionally create challenges in literature retrieval during pharmacological or ethnobotanical research, emphasizing the importance of careful taxonomic verification when conducting systematic literature searches. Synonyms include *Lonchocarpus laxiflorus* Guill. & Perr, *Lonchocarpus philenoptera* Benth, *Lonchocarpus sophiae* Kotschy & Peyr, *Philenoptera kotschyana* Fenzl, and *Philenoptera schimperi Hochst.* ex A.Rich [11]. *P. laxiflora* is known by several vernacular names across different languages and regions. In English, it is commonly referred to as 'Gambian indigo', and 'Savonnette' in French, signifying some of the plant's traditional uses or characteristics, such as its use as a dye source in the Gambia [13]. In Northern Nigeria, it is known as Halshen sa'a, Farin-sansamii, or Fura bawa in the Hausa language [14].

3.3. Morphological characteristics

P. laxiflora is a deciduous small tree or shrub that typically grows between 3 and 12 m in height, although it may occasionally reach up to 15 m. It often branches from the base and possesses a slender, somewhat crooked bole that can attain a diameter of up to 20 cm [11, 13]. The bark is fibrous, grey to brownish in color, and characteristically rough and flaking. When cut, the bark exudes a yellowish-white sap that gradually oxidizes to form a distinctive blood-red resin. The leaves are arranged alternately and are imparipinnate, measuring approximately 15–45 cm in length. Each leaf typically bears 2–3 pairs of opposite, elliptical leaflets measuring 5–18 × 2–6 cm, which are usually thinly pubescent on the lower surface. The inflorescence occurs as a terminal or axillary panicle that may reach up to 60 cm in length; it is initially erect but becomes pendulous as it matures. The flowers are papilionaceous, about 9–14 mm long, and range in color from pinkish-mauve to lilac, often displaying a conspicuous white or yellow patch on the standard petal. The fruit is a flattened, papery pod measuring approximately 6–14 × 1–2 cm, reddish-green when immature and turning pale brown at maturity. Each pod typically contains 1–4 oblong to kidney-shaped seeds (Fig. 1) [11, 13]. In the absence of flowers and fruits, *P. laxiflora* can easily be confused with *Stereospermum kunthianum* Cham. (Bignoniaceae). However, a distinguishing feature is that in *P. laxiflora* the leaf rachis extends beyond the uppermost pair of leaflets, whereas in *S. kunthianum* it does not [13].

3.4. Geographic distribution and habitat

P. laxiflora is native to tropical sub-Saharan Africa, ranging from Cape Verde and Senegal in the west to Eritrea, Ethiopia, Uganda, and the DR Congo in the east [11, 13]. The species has been reported in several countries, including Cameroon, Chad, Ghana, Guinea, Mali, Niger, Nigeria, Senegal, Sudan, and Togo, reflecting its adaptability to diverse ecological zones within the Sudano-Sahelian and savanna regions of Africa [15]. It grows primarily in savanna woodlands, dry forests, wooded grasslands, and bushland, often along forest margins or fringing watercourses. Elevations span sea level to 2,150 m on diverse soils, favoring seasonally dry tropical biomes [11, 13]. *P. laxiflora* is classified as Least Concern (LC) on the IUCN Red List, reflecting its wide distribution and lack of specific population decline threats [15].

It is not known to face specific major threats; however, in the Eastern Sudanian savanna, risks stem from subsistence agriculture via shifting cultivation and herding, as well as wood harvesting for fuel, construction, and charcoal production. Reduced rainfall exacerbates ecosystem recovery limitations from overuse [15]. In the Western region, higher population density drives greater habitat fragmentation and degradation from herding, cultivation, tree felling, wildfires, and charcoal production [15].

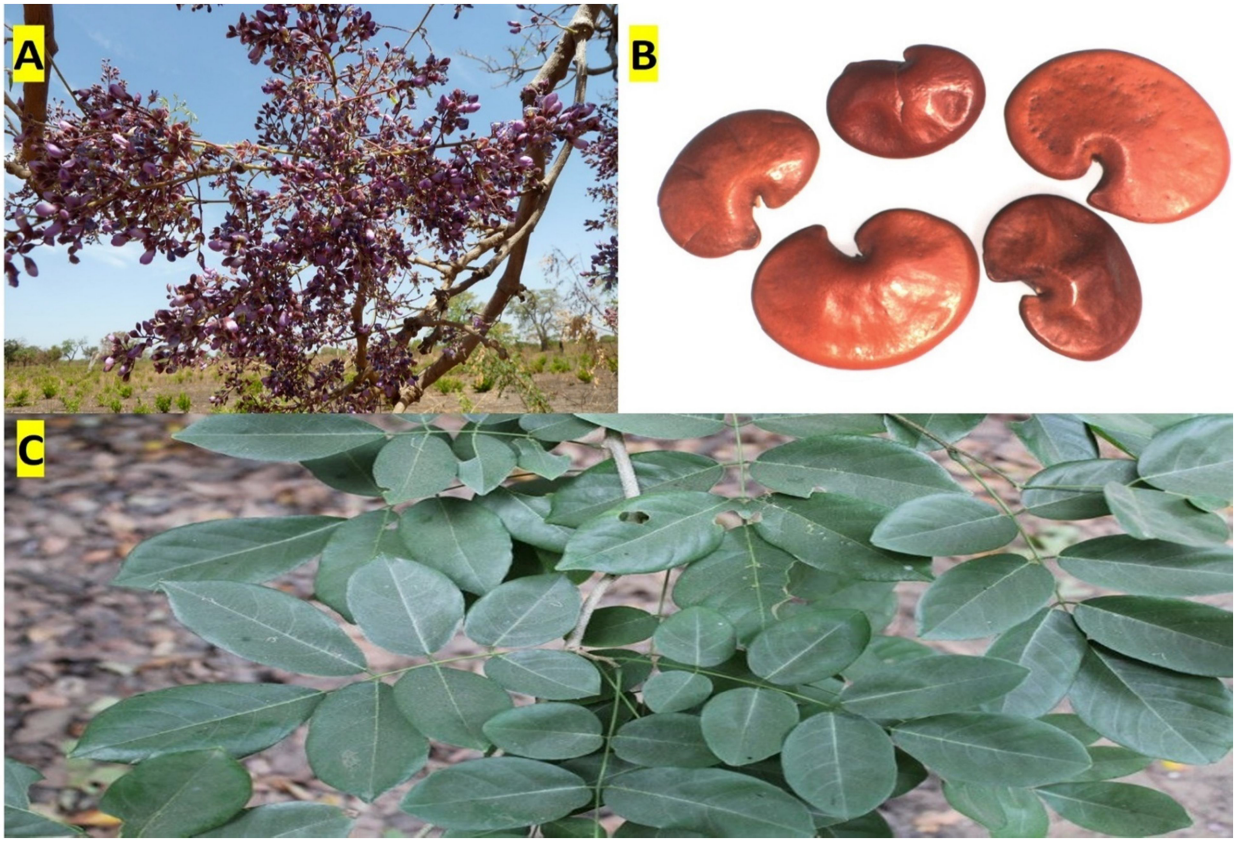

Fig. 1. Flowers (A), seeds (B), and leaves (C) of *P. laxiflora* [16].

4. Ethnomedicinal and ethnobotanical uses

P. laxiflora is widely recognized in African traditional medicine and ethnobotany for its diverse therapeutic, nutritional, and socio-economic applications. Across several African countries, different parts of the plant, including the leaves, bark, roots, seeds, flowers, and fruits, are utilized for the management of metabolic disorders, infectious diseases, gastrointestinal conditions, parasitic infections, and other ailments. A summary of the major ethnomedicinal indications and plant parts used is presented in Table 1.

In Ethiopian traditional medicine, the leaves are commonly prepared as a decoction by boiling them in water, and the resulting filtrate is administered orally for the treatment of diabetes mellitus. The plant is locally known as "Amer" in the Amharic language and is widely recognized as a traditional antidiabetic remedy [17]. In the same region, various plant parts, including the bark, leaves, and roots, are also used in the treatment of conditions broadly described as "cancer disease," although the specific cancer types are not clearly defined in traditional records [17]. Earlier ethnobotanical reports further indicate that the roots have traditionally been used for the treatment of rabies [18]. Additionally, roasted and crushed seeds are boiled to extract oil, which is applied for the treatment of warts [19]. In the Central African Republic, a decoction of young leaves is taken to treat liver disorders, while in Ethiopia, the roots are applied externally for stomach-ache [13].

Beyond Ethiopia, *P. laxiflora* is widely utilized in other African countries for the treatment of infectious and gastrointestinal disorders. In Uganda, the roots and bark are traditionally used for managing diarrhea, skin infections, parasitic infections, liver complications, and Buruli ulcer, a chronic skin disease caused by *Mycobacterium ulcerans* [20, 21]. In addition, diluted root paste is administered orally for stomach-ache [22], while the roots and bark are also used in the management of paralysis, backache, and indigestion in Erute County of Lira District [23]. In northern Nigeria, the fresh roots are chewed and swallowed as an antidote for snake venom, whereas a decoction of the stem bark combined with *Terminalia avicenno* and red potash is taken orally to manage cough, diarrhea, and sore throat [14]. The stem bark has also been reported to be used in the treatment of dermatitis, headache, intestinal worms, jaundice, ulcers, and as an anthelmintic in Nigeria [24].

Table 1. Summary of ethnomedicinal uses of *P. laxiflora*.

Use category	Plant part(s)	Preparation/Application	Region/Country	Reference
Diabetes mellitus	Leaves	Decoction taken orally	Ethiopia	[17]
Cancer (unspecified)	Bark, leaves, roots	Not specified	Ethiopia	[17]
Rabies	Roots	Not specified	Ethiopia	[18]
Wart	Seeds	Roasted, crushed, boiled to extract oil applied topically	Ethiopia	[19]
Liver disorders	Young leaves	Decoction taken orally	Central African Republic	[13]
Stomach-ache	Roots	External application or diluted paste	Ethiopia, Uganda	[22]
Diarrhea, skin infections, parasitic infections, Buruli ulcer	Roots, bark	Not specified	Uganda	[20, 21]
Paralysis, backache, indigestion	Roots, bark	Not specified	Uganda	[23]
Snake venom antidote	Roots	Fresh roots chewed and swallowed	Nigeria	[14]
Cough, diarrhea, sore throat	Stem bark	Decoction with *Terminalia avicenno* and red potash	Nigeria	[14]
Dermatitis, intestinal worms, jaundice, ulcer	Stem bark	Not specified	Nigeria	[24]
Urinary schistosomiasis	Bark	Decoction with *Stylosanthes erecta*, *Cissus quadrangularis*, *Tamarindus indica*	West Africa	[26]
HIV/AIDS	Root bark	Not specified	East Africa	[27]
Infectious coryza (poultry)	Leaves, bark	Pounded preparation	Uganda	[21]
Trypanosomiasis (animals)	Stem bark	Mixed with guinea corn flour and potash	Nigeria	[32]
Foot-and-mouth disease (livestock)	Bark, roots	Decoction administered orally	Burkina Faso	[30]
Snakebite	Leaves, roots	Not specified	Burkina Faso	[29]
Indigo dye production	Leaves	Source of natural indigo dye	West Africa, Sudan, DR Congo	[13].
Traditional textile dyeing (“bara siti”)	Leaves	Tie-and-dye technique	Gambia, Senegal	[13]
Food (vegetable)	Young leaves	Cooked vegetable	Central African Republic	[13]
Food (fruits, flowers)	Fruits, flowers	Cooked with potherbs or sesame paste; fruits dried for storage	Central African Republic	[13]
Condiment ingredient	Bark	Added to condiment mixtures	Senegal, Guinea	[13]
Fodder	Leaves	Browsed by livestock	Various regions	[13]
Timber and fuel	Wood	Poles, fuelwood, charcoal	Various regions	[13]
Dental hygiene	Stem, bark	Chewing stick	Nigeria (Igede people)	[25]
Arrow poison	Stem, bark	Arrow poison	Nigeria (Igede people)	[25]
Ornamental use	Whole plant	Ornamental flowering tree	Tropical regions	[13]

Ethnobotanical records also note cultural uses among the Igede people of Nigeria, where the stem is used as a chewing stick for dental hygiene. At the same time, the bark is utilized as an arrow poison [25].

Other traditional formulations include a decoction of the bark combined with aerial parts of *Stylosanthes erecta* and *Cissus quadrangularis*, with the addition of *Tamarindus indica* fruit after cooling, which is administered twice daily for 15–30 days to treat urinary schistosomiasis [26]. Furthermore, root bark preparations have been reported in the management of HIV/AIDS in certain African communities [27]. The plant has also been employed in the treatment of mental disorders, skin infections, jaundice, intestinal worms, and reproductive disorders across countries such as Nigeria, Benin, Kenya, and Senegal [28]. In Uganda, the leaves are used to treat diarrhea and malaria, and the leaves and roots are applied for snakebite [29].

Additional ethnomedicinal records indicate that *P. laxiflora* is widely utilized across several African countries for diverse therapeutic and cultural purposes. In Benin, complex herbal formulations incorporating the roots are used to manage mental illness, where a decoction of the roots, combined with Cymbopogon schoenanthus, Hymenocardia acida, and the leaves of Vitex simplicifolia, is administered orally and applied in vapor baths [16]. In the same region, a decoction of leafy twigs mixed with those of *Byrsocarpus coccineus* is used both as a drink and a topical lotion for the treatment of dermatitis. At the same time, powder obtained from calcined roots

is applied to the forehead to relieve headache. In the Central African Republic, the Lissongo people macerate the root to prepare a drink used for treating intestinal worms. Traditional medicinal uses are also documented in other parts of Africa: in northern Gambia the plant is employed for managing women's reproductive disorders; in Kenya, root infusions are used to treat back pain and paralysis; and in northern Nigeria, leaf-based remedies are applied to treat foot ulcers, while bark and root preparations are used as tonics, for jaundice, and as anthelmintic agents [16]. In Senegal, Bambara traditional practitioners use the roots to treat leprosy and intestinal disorders. In Togo, the root bark is incorporated into complex preparations for leprosy treatment, including fumigation mixtures with *Stereospermum kunthianum* and elephant excrement, or decoctions combined with roots of *Parkia biglobosa* and *Vitellaria paradoxa* [16]. Additional ethnomedicinal applications include the use of decoctions as topical lotions for venereal diseases, treatments for childhood constipation, skin disorders, and remedies for sterility associated with insufficient semen [16].

The plant also plays an important role in ethnoveterinary medicine. In Burkina Faso, decoctions of the bark and roots are administered orally to treat foot-and-mouth disease in livestock [30]. In Uganda, the leaves and bark are pounded and used to treat infectious coryza in poultry, a contagious respiratory disease caused by *Avibacterium paragallinarum* [21]. Similarly, the stem bark mixed with guinea corn flour and potash is used to treat trypanosomiasis in animals [30], while bark decoctions are used to treat diarrhea in livestock [31]. In Nigeria and Sudan, leaves are also applied as poultices for ulcers, and bark decoctions are used to treat intestinal disorders in horses. In addition, leaves and bark are used as insecticidal and external antiparasitic agents for the treatment of scabies and ringworm in Nigeria [13].

Apart from medicinal uses, *P. laxiflora* also has several ethnobotanical and socio-economic applications. In West Africa, particularly in Senegal, The Gambia, and northern Nigeria, as well as in the Kordofan Province of western Sudan and the Kasango region of eastern Democratic Republic of Congo, the leaves have traditionally been used as a source of indigo dye. The dye is prepared like that derived from *Philenoptera cyanescens* and *Indigofera arrecta*, producing comparable shades of blue [13]. In Gambia, this dye has historically been used in the production of the well-known "bara siti" textile, where decorative patterns are created using a tie-and-dye technique that involves crumpling and binding sections of cloth before dyeing. This technique is believed to have originated among the Soninké people of Senegal [13]. The plant also holds cultural significance. Among the Acholi people of northern Uganda, branches of *P. laxiflora* are traditionally used in ritual practices to bless warriors' weapons before battle, while in the nearby Apac District, the branches are sprinkled with water around homes to ward off evil spirits [16].

P. laxiflora also contributes to local food systems in some regions. In the Central African Republic, young leaves are consumed as cooked vegetables, while the Gbaya people eat the flowers and fresh young fruits [13]. The fruits may also be cooked with potherbs and sesame paste, and after boiling they can be dried and stored for later use. In Senegal and Guinea, the bark is incorporated into condiment mixtures by the Tenda people. The leaves are also browsed by livestock or used as fodder for goats [13]. In addition, the wood is commonly used for pole timber and as a source of fuelwood and charcoal. Owing to its profuse panicles of delicately scented blue or pinkish flowers, *P. laxiflora* also possesses potential as an ornamental tree in tropical landscapes [22].

5. Phytochemical composition

Despite its widespread ethnomedicinal use, *P. laxiflora* has received relatively little phytochemical investigation compared with many other African medicinal legumes, and its chemical profile remains only partially characterized. Nevertheless, available studies indicate that the species contains a diverse array of secondary metabolites belonging to several phytochemical classes (Fig. 2). Preliminary phytochemical screening has reported the presence of alkaloids, saponins, flavonoids, phenolic compounds, tannins, steroids, terpenoids, and anthraquinones [17, 33].

Detailed phytochemical investigations have led to the isolation of several structurally distinct compounds from the plant. Notably, three novel cassane-type diterpenoids, lonchocassane A, lonchocassane B, and lonchocassane C were identified from *P. laxiflora* [34]. In addition to these new compounds, a range of known triterpenoids, sterols, and other constituents have been isolated, including betulinic acid, betulinic acid acetate, betulin, lupeol, lupenone, hexacosanyl and triacontanyl caffeates, trilinoleate, 4-hydroxy-4-methylpentan-2-one, β-sitosterol, β-sitosterol acetate, and [34]. These compounds belong primarily to the triterpenoid and phytosterol classes, which are frequently associated with anti-inflammatory, antimicrobial, and anticancer activities.

Earlier chemical studies also reported the isolation of two new isoflavans, (–)-dihydropterocarpin and (–)-dihydrohomopterocarpin, together with two

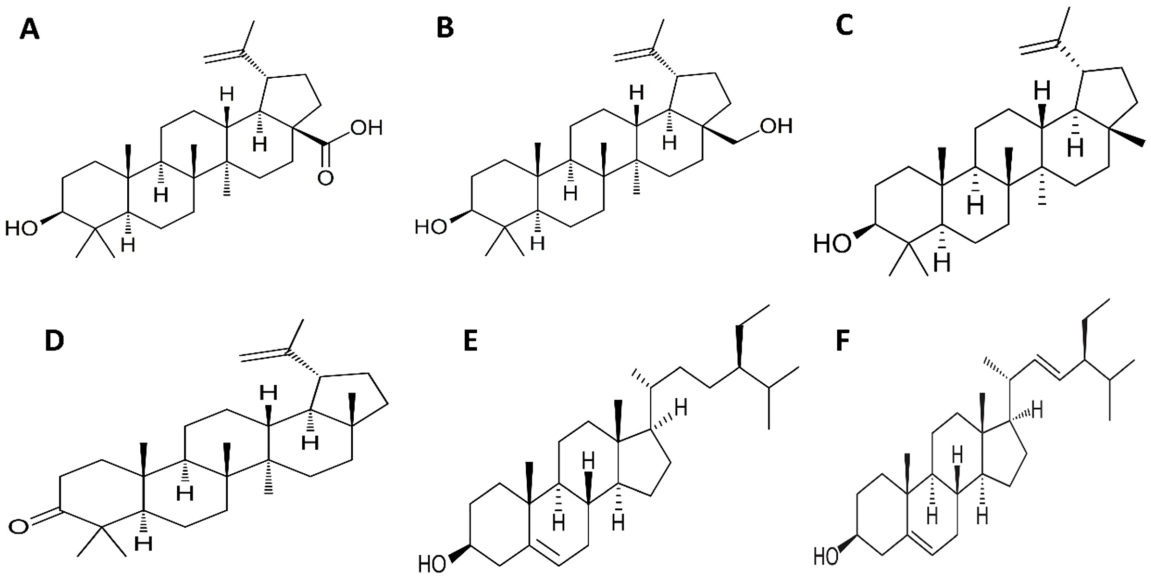

Fig. 2. Structure of some isolated compounds from *P. laxiflora*. A = Betulinic acid; B = Betulin; C = Lupeol; D = Lupenone; E = β -sitosterol; F = Stigmasterol.

novel pterocarpans from *P. laxiflora* [35]. Structural elucidation revealed that these compounds share similar configurations at the C-3 position. Their characterization involved spectroscopic analyses, including methoxy-proton shifts and infrared stretching frequencies, while mass spectrometric data confirmed the presence of hydroxyl groups on the aromatic rings. These findings highlight the occurrence of isoflavonoid derivatives within the species, further emphasizing the structural diversity of its secondary metabolites [35].

6. Pharmacological activities

Pharmacological studies on *P. laxiflora* are still in their early stages and have largely involved testing crude extracts in vitro and in limited animal models, as summarized in Table 2. No clinical trials have been reported for this species to date. Nevertheless, available investigations have revealed several bioactivities that align with its traditional uses. For example, cytotoxic (anticancer) activity has been demonstrated by stem-bark extracts. In one study, petroleum ether, ethyl acetate, and methanol extracts of the stem bark were tested by the brine-shrimp lethality assay (BSLT) and by MTT assays on four human breast cancer cell lines (MCF-7, Hs578T, SkBr3, and MDA-MB-231) [28]. All extracts showed high general toxicity in the BSLT ($LC_{50} \approx$ 51–67 μg/mL), with the methanol fraction being the most toxic (LC_{50} = 51.5 μg/mL) [28]. In the MTT assay, the methanol extract was most potent against MCF-7 cells ($IC;_{50}$ = 67 μM), essentially matching the reference drug etoposide (IC_{50} = 68 μM) [28]. The n-hexane and ethyl acetate fractions showed moderate cytotoxicity across all four cell lines, with IC_{50} values higher than the methanol extract [28]. These findings indicate that *P. laxiflora* stem bark contains constituents with strong cytotoxic potential against breast cancer cells (including triple-negative subtypes), providing a scientific basis for its traditional use in treating malignancies.

Another well-documented activity is the antidiabetic (antihyperglycemic) effect, consistent with Ethiopian traditional use of the leaves for the treatment of diabetes. An 80% methanol extract of *L. laxiflorus* leaves was evaluated in mouse models [17]. The extract was found to be safe up to a high dose (2000 mg/kg) [17]. In normoglycemic Swiss albino mice, oral doses of 200–400 mg/kg produced significant blood-glucose reductions within 2–4 hours of administration. In glucose-tolerance tests, the same doses markedly suppressed post-prandial hyperglycemia, comparable to the standard drug glibenclamide [17]. Crucially, in streptozotocin-induced diabetic mice, the extract (200 and 400 mg/kg) significantly lowered fasting blood glucose and improved the serum lipid profile (reducing total cholesterol and triglycerides while raising HDL) [17]. These results confirm that *P. laxiflora* leaf extract has pronounced antihyperglycemic and antidyslipidemic effects in vivo, supporting its traditional use as an antidiabetic remedy.

Table 2. Summary of reported pharmacological activities.

Activity	Plant part/Extract	Experimental model	Key findings	Reference
Cytotoxic (anticancer)	Stem bark (n-hexane, ethyl acetate, methanol extracts)	In vitro (Brine Shrimp Lethality; MTT on breast cancer cell lines: MCF-7, Hs578T, SkBr3, MDA-MB-231)	High toxicity in BSLT (LC_{50} ~51–67 μg/mL); methanol extract most potent. Methanol extract IC_{50} ~67 μM on MCF-7 (≈ etoposide IC_{50} 68 μM); n-hexane/EtOAc extracts moderately active.	[28]
Antihyperglycemic (antidiabetic)	Leaves (80% methanolic extract)	In vivo (normoglycemic and STZ-induced diabetic mice; oral glucose tolerance test)	Safe to 2000 mg/kg. At 200–400 mg/kg, significantly lowers blood glucose in normal and STZ-diabetic mice; improves glucose tolerance and lipid profile (↓cholesterol, ↓triglycerides, ↑HDL) comparable to glibenclamide.	[17]
Antibacterial	Roots (methanolic extract)	In vitro (agar diffusion against *S. aureus*, *P. aeruginosa*, *E. coli*)	Active against *S. aureus* and *P. aeruginosa*. Zones of inhibition: *S. aureus* ~9.7 mm at 25 mg/mL rising to 20.0 mm at 100 mg/mL; *P. aeruginosa* ~9.3 mm (25 mg/mL) to 18.3 mm (100 mg/mL). *E. coli* less sensitive.	[33]
Antitrypanosomal	Stem bark (petroleum ether, chloroform, methanol extracts)	In vitro (motility assay on *Trypanosoma brucei*)	All extracts showed strong trypanocidal activity. At 4 mg/mL, petroleum ether and methanol extracts ceased parasite motility by ~45 min, chloroform extract by ~25 min. (No in vivo data reported.)	[36]

Consistent with its ethnomedicinal use for infections, *P. laxiflora* also shows antimicrobial activity in vitro. In one study, the methanolic extract of the roots was tested against common bacterial pathogens [33]. The extract inhibited *Staphylococcus aureus* and *Pseudomonas aeruginosa* appreciably even at low concentrations. For instance, at 25 mg/mL, the extract produced zones of inhibition of ~9.7 mm against *S. aureus* and ~9.3 mm against *P. aeruginosa*, indicating modest activity at a relatively low dose. Activity increased with dose (reaching 20.0 mm and 18.3 mm, respectively, at 100 mg/mL). *Escherichia coli* was less sensitive, showing no inhibition below 50 mg/mL [33]. These results corroborate local usage of the plant for skin and gastrointestinal infections and suggest potential utility against Gram-positive and Gram-negative bacteria.

Furthermore, *P. laxiflora* has shown antiparasitic (antitrypanosomal) activity in vitro. A comparative study of crude extracts from Nigerian savanna plants found that petroleum ether, chloroform, and methanol extracts of *L. laxiflorus* stem bark all drastically reduced the motility of *Trypanosoma brucei* tachyzoites in short-term assays [36]. For example, a 4 mg/mL dose of the petroleum ether and methanol extracts completely immobilized the parasites by 45 minutes, and the chloroform extract achieved immobility by 25 minutes [36]. No in vivo (animal) trypanosome studies are reported for *P. laxiflora*, but these in vitro data suggest potential utility in treating African trypanosomiasis and related livestock diseases, in line with its ethnoveterinary use.

7. Toxicological and safety profile

Scientific studies on the safety of *P. laxiflora* are limited but consistently indicate a high margin of safety for the leaf extracts. Key findings from acute and sub-chronic toxicity tests in rodents are summarized below in Table 3.

Acute toxicity of the methanol leaf extract was evaluated following OECD guidelines. Rats administered a single oral dose of 5000 mg/kg showed no mortality or observable adverse clinical signs during the 14-day observation period. Thus, the median lethal dose (LD_{50}) was estimated to be greater than 3000 mg/kg, classifying the extract as practically non-toxic (OECD Category 5). No behavioral or physical abnormalities were observed during the observation period, supporting a very low acute toxicity [37].

Sub-chronic toxicity was assessed in a 28-day repeated-dose study in which rats received daily oral doses of 250, 500, 750, or 1000 mg/kg of the extract [37]. Body-weight gain remained largely

Table 3. Summary of toxicological findings for *P. laxiflora*.

Assessment	Extract/Dose	Model/Duration	Major Findings	Reference
Acute toxicity (LD_{50})	Leaf methanol extract (single 5000 mg/kg)	Rat, observed 14 days	No mortality or overt toxicity; LD_{50} > 3000 mg/kg	[37]
Sub-chronic toxicity	Leaf methanol extract (250–1000 mg/kg daily)	Rat, 28 days	Body weight largely unchanged; no significant organ weight or clinical chemistry changes. No signs of hepato- or nephrotoxicity.	[37]
Hematology	Same as above	Rat, 28 days	Major blood counts showed no significant differences vs. control. Minor lymphocyte increase and granulocyte decrease noted at high dose.	[37]
Histopathology	Same as above	Rat, 28 days	Liver and kidney tissues showed *normal architecture* at all doses. No pathological lesions observed.	[37]

unaffected across all treatment groups, with no significant differences compared to controls except for minor transient variations at certain time points. Biochemical markers of hepatic and renal function remained within normal limits. Serum aspartate aminotransferase (AST), total protein, and bilirubin levels showed no significant changes ($P > 0.05$), while renal function indicators, including creatinine, urea, uric acid, and serum electrolytes (Na^+, K^+, Cl^-, and HCO_3^-) also comparable to control values [37]. Hematological parameters, including white and red blood cell counts, hemoglobin, hematocrit, and platelet levels, remained stable, with only minor variations that stayed within normal physiological ranges, indicating no evidence of hepatotoxicity or nephrotoxicity following 28 days of administration [37].

Histopathological examination further supported these findings. Liver tissues from treated animals displayed normal architecture, including intact central veins, portal triads, and hepatocytes, comparable to the control group. Similarly, kidney sections revealed preserved glomerular and tubular structures with no evidence of lesions, inflammation, or necrosis [37]. These observations confirm that repeated oral administration of the extract at doses up to 1000 mg/kg/day did not induce structural damage to the liver or kidneys.

8. Research gaps and future directions

Despite the extensive ethnomedicinal use of *P. laxiflora* across several African regions, the plant remains scientifically underexplored, and the documented ethnomedicinal uses reports lack detailed information regarding dosage, preparation standardization, and treatment outcomes. Additionally, ethnobotanical documentation for *P. laxiflora* remains geographically limited, suggesting that further field studies may reveal additional traditional uses not yet recorded in the scientific literature. Notwithstanding, ethnobotanical records demonstrate its application in the management of diverse conditions, but preliminary pharmacological studies partially support these traditional claims. The few available investigations remain at an early stage, focusing primarily on crude extract screening and basic in vitro assays. Consequently, significant knowledge gaps persist regarding the plant's phytochemical diversity, molecular mechanisms of action, pharmacokinetics, and translational therapeutic potential. Addressing these gaps is essential to fully harness the immense pharmacological promise of *P. laxiflora* and to position it as a viable candidate for modern drug discovery.

One of the most significant research gaps lies in the incomplete phytochemical characterization of the species. Although preliminary studies have reported the presence of several classes of secondary metabolites, the majority of these compounds remain unidentified or insufficiently characterized. Only a limited number of isolated constituents, such as cassane-type diterpenoids and isoflavonoid derivatives, have been structurally elucidated. Considering the rich chemical diversity typically associated with the Fabaceae family, it is highly probable that *P. laxiflora* contains numerous undiscovered bioactive molecules. Future studies should therefore prioritize comprehensive phytochemical investigations using advanced analytical techniques. Such approaches would enable the identification of novel natural products with unique structural scaffolds that could serve as lead compounds in pharmaceutical development.

Another major limitation in current research is the reliance on crude extracts for pharmacological evaluation. While crude extracts provide preliminary insights into biological activity, they do not allow precise attribution of therapeutic effects to specific compounds. Bioassay-guided fractionation is therefore necessary to isolate and identify the active constituents responsible for the observed pharmacological activities [38]. This strategy involves systematic fractionation of plant extracts followed by biological screening of each fraction to pinpoint the most active components. Once isolated, these compounds can undergo detailed pharmacological characterization and structural modification through medicinal chemistry approaches [38]. Such work may ultimately yield novel therapeutic agents targeting diseases such as cancer, diabetes, microbial infections, and parasitic disorders.

Mechanistic pharmacological studies also remain largely absent for *P. laxiflora*. Most current investigations report phenotypic biological effects, such as antimicrobial inhibition zones or reductions in blood glucose levels, without elucidating the underlying molecular pathways involved. Understanding the mechanisms of action of bioactive compounds is crucial for validating therapeutic efficacy and guiding drug development [39]. Future research should therefore incorporate molecular and cellular studies to identify relevant biological targets. Techniques such as enzyme inhibition assays, gene expression analysis, proteomics, receptor-binding studies, and pathway-specific assays can provide deeper insights into how *P. laxiflora* extracts and compounds exert their pharmacological effects. Integrating computational tools such as molecular docking, molecular dynamics simulations, and network pharmacology may further accelerate the identification of potential therapeutic targets and drug candidates.

Another critical research gap concerns the limited scope of pharmacological investigations conducted so far. Existing studies have primarily focused on antimicrobial, antidiabetic, cytotoxic, and antiparasitic activities. However, the plant's extensive traditional use suggests the possibility of a much broader pharmacological spectrum. For example, ethnomedicinal reports describe its use in treating inflammatory diseases, liver disorders, mental illnesses, reproductive problems, and dermatological conditions. These indications remain largely unverified scientifically. Future pharmacological studies should therefore expand the range of investigated bioactivities to include anti-inflammatory, hepatoprotective, neuroprotective, immunomodulatory, antiviral, and wound-healing effects. Such studies would not only validate traditional knowledge but also uncover additional therapeutic applications.

Toxicological evaluation of *P. laxiflora* also remains incomplete. Although acute and sub-chronic toxicity studies indicate a favorable safety profile with no significant adverse effects in experimental animals, these findings are insufficient for long-term therapeutic development. Moreover, the study covers only one extract and has a limited duration. Critical toxicological aspects, including chronic toxicity, reproductive toxicity, teratogenicity, genotoxicity, and carcinogenicity, have not yet been investigated. Furthermore, information regarding pharmacokinetics, metabolism, and bioavailability of the plant's bioactive compounds is lacking. Comprehensive toxicological and pharmacokinetic studies are therefore essential to establish the safety margins and therapeutic indices of potential drug candidates derived from the plant.

Standardization and quality control represent another important area requiring attention. Traditional preparations of *P. laxiflora* vary widely in terms of plant parts used, extraction methods, dosage, and duration of treatment. Such variability can lead to inconsistent pharmacological outcomes and complicate the reproducibility of research findings [40]. Future studies should aim to develop standardized extracts with well-defined phytochemical profiles and consistent concentrations of active compounds. Establishing pharmacognostic parameters, chromatographic fingerprints, and validated analytical methods will be crucial for ensuring quality control in both research and potential clinical applications [41].

In addition, the clinical potential of *P. laxiflora* remains entirely unexplored. To date, no clinical trials have been conducted to evaluate the efficacy or safety of its preparations in human populations. Bridging this gap requires a stepwise translational research framework beginning with detailed preclinical studies, followed by well-designed clinical trials. Such trials could initially focus on conditions where both traditional use and experimental evidence converge, such as diabetes, microbial infections, and inflammatory diseases. Successful clinical validation would significantly enhance the plant's credibility as a source of therapeutic agents and could pave the way for the development of phytopharmaceuticals.

9. Conclusion

P. laxiflora is a medicinal plant of considerable ethnopharmacological significance in many parts of sub-Saharan Africa. Preliminary scientific investigations have begun to support several of these

traditional claims, with studies demonstrating antimicrobial, antihyperglycemic, cytotoxic, and antiparasitic activities. These pharmacological effects are attributed to the plant's diverse phytochemical composition, which includes flavonoids, isoflavonoids, triterpenoids, phenolic compounds, tannins, and other bioactive secondary metabolites. Available toxicological studies also indicate a favorable safety profile, with acute and sub-chronic evaluations showing no significant adverse effects in experimental models. Despite these promising findings, *P. laxiflora* remains relatively underexplored scientifically. If fully explored, *P. laxiflora* has the potential to serve as a valuable source of novel therapeutic agents addressing major global health challenges.

Acknowledgement

Not applicable.

Ethical statement

Not applicable.

Data availability statement

All data supporting the findings of this study are available within the manuscript.

Funding statement

This review received no external funding.

Conflicts of interest

The author declares that there is no conflict of interest.

References

1. N. Chaachouay and L. Zidane, "Plant-derived natural products: a source for drug discovery and development," *Drugs Drug Candidates*, vol. 3, pp. 184–207, 2024, https://doi.org/10.3390/ddc3010011.
2. A. Najmi, S. A Javed, M. Al Bratty, and H. A Alhazmi, "Modern approaches in the discovery and development of plant-based natural products and their analogues as potential therapeutic agents," *Molecules*, vol. 27, p. 349, 2022, https://doi.org/10.3390/molecules27020349.
3. J. B Calixto, "The role of natural products in modern drug discovery," *An Acad Bras Ciênc*, vol. 91, p. e20190105, 2019, https://doi.org/10.1590/0001-3765201920190105.
4. B. Wang, Q. Liu, W. Zhao, T. Zhang, D. Zhang, C. Sutcharitchan, *et al.*, "Revolutionizing drug discovery from natural products: the roles of artificial intelligence and multi-omics in accelerating innovation," *Acta Pharm Sin B*, p. S221138352500838X, 2025, https://doi.org/10.1016/j.apsb.2025.12.030.
5. I. Mutebi, "Ethnopharmacology: engineering plant-based therapeutics," *NEWPORT Int J Sci Exp Sci*, vol. 6, pp. 51–61, 2025, https://doi.org/10.59298/NIJSES/2025/63.5161.
6. R. Latif and T. Nawaz, "Medicinal plants and human health: a comprehensive review of bioactive compounds, therapeutic effects, and applications," *Phytochem Rev*, 2025, https://doi.org/10.1007/s11101-025-10194-7.
7. E. Karalija, A. Macanović, and S. Ibragić, "Revisiting traditional medicinal plants: integrating multiomics, in vitro culture, and elicitation to unlock bioactive potential," *Plants*, vol. 14, p. 2029, 2025, https://doi.org/10.3390/plants14132029.
8. P. R Gutiérrez-Durán, J. V Horta-Vega, F. E Olazarán-Santibáñez, J. Flores-Gracia, and H. B Barrios-García, "Phytochemical diversity and antimicrobial potential of fabaceae species occurring in tamaulipas, Mexico: a systematic review," *Plants*, vol. 15, p. 278, 2026, https://doi.org/10.3390/plants15020278.
9. P. Jadhavar and S. Deshpande, "Recent updates on medicinal potentiality of fabaceae family: critical review," *Int J Pharma Bio Sci*, vol. 13, 2022, https://doi.org/10.22376/Ijpbs.2022.13.3.b32-41.
10. A. Maroyi, "Medicinal uses of the fabaceae family in Zimbabwe: a review," *Plants*, vol. 12, p. 1255, 2023, https://doi.org/10.3390/plants12061255.
11. Useful Tropical Plants. Philenoptera laxiflora, 2026, https://tropical.theferns.info/viewtropical.php?id=Philenoptera+laxiflora (accessed March 8, 2026).
12. S. M Isyaka, O. A Olayemi, and A. M Abdullahi, "Phytochemistry and medicinal uses of lonchocarpus species: systematic review of a promising medicinal plant," *South Asian Res J Nat Prod*, vol. 8, pp. 32–44, 2025, https://doi.org/10.9734/sarjnp/2025/v8i1178.
13. D. Cardon and P. Jansen, Philenoptera laxiflora (Guill. & Perr.) Roberty, 2005, https://prota.prota4u.org/protav8.asp?g=pe&p=Philenoptera+laxiflora (accessed March 8, 2026).
14. U. M Umar and I. T Babalola, "Ethnomedical survey of medicinal plants used by three indigenous tribes in Yobe state, Nigeria," *Tradit Folk Herb Med Recent Res*, vol. 3, pp. 469–86, 2016.
15. A. Groom, "IUCN red list of threatened species: philenoptera laxiflora," *IUCN Red List Threat Species*, 2010.
16. iNaturalist. Philenoptera laxiflora (Guill. & Perr.) Roberty. Plants World Online. Available at: https://www.inaturalist.org/taxa/138397-Philenoptera-laxiflora (accessed March 8, 2026).
17. G. T Desta, Y. A Ferede, W. S Zewdu, B. Y Adugna, T. Arega, and M. A Alemu, "Validation of antidiabetic and antihyperlipidemic effects of 80% methanolic extract of the lonchocarpus laxiflorus leaves in streptozotocin-induced diabetic swiss albino mice," *Evid Based Complement Alternat Med*, vol. 2022, p. 8411851, 2022, https://doi.org/10.1155/2022/8411851.
18. R. Pankhurst, "The history and traditional treatment of rabies in Ethiopia," *Med Hist*, vol. 14, pp. 378–89, 1970, https://doi.org/10.1017/s0025727300015829.
19. T. Gebretsadkan, "Ethnobotanical study of medicinal plants used by people of Gog District, Agnuak Zone, Gambella Regional State of Ethiopia," PhD Thesis. MSc Thesis, Haramaya University, 2017.

20. M. M Alemu, “Natural regeneration status of the ground water forest in Nech Sar National Park, Ethiopia,” *Environ Nat Resour Res*, vol. 7, p. 1, 2017, https://doi.org/10.5539/enrr.v7n2p1.
21. G. Zirintunda, J. Kateregga, S. Nalule, P. Vudriko, S. Biryomumaisho, and J. O Acai, “An inventory of ethnoveterinary knowledge for chicken disease control in Soroti district, Uganda,” *J Med Plants Econ Dev*, vol. 8, p. 248, 2024, https://doi.org/10.4102/jomped.v8i1.248.
22. E. T Masters, “Medicinal plants of the upper Aswa River catchment of northern Uganda - a cultural crossroads,” *J Ethnobiol Ethnomedicine*, vol. 19, p. 48, 2023, https://doi.org/10.1186/s13002-023-00620-5.
23. C. Oryema, R. B Ziraba, N. Omagor, and A. Opio, “Medicinal plants of Erute county, Lira district, Uganda with particular reference to their conservation,” *Afr J Ecol*, vol. 48, pp. 285–98, 2010, https://doi.org/10.1111/j.1365-2028.2009.01147.x.
24. Y. Rabe, “The studies of anti-trypanosomal activity of selected plants extracts against dimenazene aceturate®resistant strains of Trypanosoma Brucei and T. Congolense isolates,” *Acad J Multidiscip Dr Res*, vol. 1, pp. 95–105, 2023.
25. J. O Igoli, I. C Igwue, and N. P Igoli, “Traditional medicinal practices among the Igede People of Nigeria,” *J Herbs Spices Med Plants*, vol. 10, pp. 1–10, 2004, https://doi.org/10.1300/J044v10n04_01.
26. S. Bah, D. Diallo, S. Dembélé, and B. S Paulsen, “Ethnopharmacological survey of plants used for the treatment of schistosomiasis in Niono District, Mali,” *J Ethnopharmacol*, vol. 105, pp. 387–99, 2006.
27. M. Lamorde, J. R S. Tabuti, C. Obua, C. Kukunda-Byobona, H. Lanyero, P. Byakika-Kibwika, *et al.*, “Medicinal plants used by traditional medicine practitioners for the treatment of HIV/AIDS and related conditions in Uganda,” *J Ethnopharmacol*, vol. 130, pp. 43–53, 2010, https://doi.org/10.1016/j.jep.2010.04.004.
28. F. K Ali, B. Adedoyin, A. Umar, J. S Wakawa, and O. A Olayemi, “In vitro cytotoxicity of lonchocarpus laxiflorus for breast cancer therapy,” *10th Annu Symp ACS Niger*, 2025.
29. M. Kristensen and H. Balslev, “Perceptions, use and availability of woody plants among the Gourounsi in Burkina Faso,” *Biodivers Conserv*, vol. 12, pp. 1715–39, 2003, https://doi.org/10.1023/A:1023614816878.
30. T. M Kpodékon, C. A Ogni, H. Dassou, T. J Dougnon, C. Boko, G. B Koutinhouin, *et al.*, “Dominant viral pathologies in the extensive and semi-intensive animal breeding and their treatment mode in ethno veterinary medicine in Benin,” *Vet World*, vol. 8, pp. 1424–34, 2015, https://doi.org/10.14202/vetworld.2015.1424-1434.
31. T. D Stark, D. J Mtui, and O. B Balemba, “Ethnopharmacological survey of plants used in the traditional treatment of gastrointestinal pain, inflammation and diarrhea in Africa: future perspectives for integration into modern medicine,” *Animals*, vol. 3, pp. 158–227, 2013, https://doi.org/10.3390/ani3010158.
32. S. E Atawodi, D. A Ameh, S. Ibrahim, J. N Andrew, H. C Nzelibe, E. O Onyike, *et al.*, “Indigenous knowledge system for treatment of trypanosomiasis in Kaduna state of Nigeria,” *J Ethnopharmacol*, vol. 79, pp. 279–82, 2002.
33. I. Sani, S. A Jega, B. M Danbare, F. Bello, A. Abdulhamid, A. Abubakar, *et al.*, “Antibacterial activities of some medicinal plants on common multidrug-resistant bacterial isolates from some patients attending federal medical center, Birnin Kebbi, Nigeria,” *J Biotechnol Res*, pp. 1–6, 2022, https://doi.org/10.32861/jbr.81.1.6.
34. J. O Igoli, S. O Onyiriuka, M. C Letzel, M. N Nwaji, and A. I Gray, “Cassane diterpenoids from *Lonchocarpus laxiflorus*,” *Nat Prod Commun*, vol. 3, p. 1934578×0800300102, 2008, https://doi.org/10.1177/1934578\times0800300102.
35. A. Pelter and P. I Amenechi, “Isoflavonoid and pterocarpinoid extractives of Lonchocarpus laxiflorus,” *J Chem Soc C Org*, vol. 887, 1969, https://doi.org/10.1039/j39690000887.
36. K. Makeri, “Comparative in vitro trypanocidal activities of petroleum ether, chloroform, methanol and aqueous extracts of some Nigerian savannah plants,” *Afr J Biotechnol*, 2005, https://doi.org/10.5897/AJB2005.000-3035.
37. A. Abdulhamid, A. Nnenna Ukwuani-Kwaja, H. Mustapha Hassan, A. Zubairu, H. Ibrahim Namaki, and S. Ibrahim Mungadi, “Acute and sub-acute toxicity study of Lonchocarpus laxiflorus leaf methanol extract on albino rats,” *Drug Discov*, vol. 18, pp. 1–10, 2024, https://doi.org/10.54905/disssi.v18i42.e18dd1999.
38. C. Barba-Ostria, S. E Carrera-Pacheco, R. Gonzalez-Pastor, J. Heredia-Moya, A. Mayorga-Ramos, C. Rodríguez-Pólit, *et al.*, “Evaluation of biological activity of natural compounds: current trends and methods,” *Molecules*, vol. 27, p. 4490, 2022, https://doi.org/10.3390/molecules27144490.
39. A. Narayanankutty, A. C Famurewa, and E. Oprea, “Natural bioactive compounds and human health,” *Molecules*, vol. 29, p. 3372, 2024, https://doi.org/10.3390/molecules29143372.
40. L. C Klein-Junior, M. R De Souza, J. Viaene, T. M B. Bresolin, A. L De Gasper, A. T Henriques, *et al.*, “Quality control of herbal medicines: from traditional techniques to state-of-the-art approaches,” *Planta Med*, vol. 87, pp. 964–88, 2021, https://doi.org/10.1055/a-1529-8339.
41. E. Noviana, G. Indrayanto, and A. Rohman, “Advances in fingerprint analysis for standardization and quality control of herbal medicines,” *Front Pharmacol*, vol. 13, p. 853023, 2022, https://doi.org/10.3389/fphar.2022.853023.