A review on medicinal and ethnomedicinal uses, biological features, and phytochemical constituents of Sesbania sesban L. Merr., a nitrogen-fixing plant native to the Republic of Chad

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A review on medicinal and ethnomedicinal uses, biological features and phytochemical constituents of *Sesbania sesban* L. Merr., a nitrogen-fixing plant native to the Republic of Chad

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Abstract

This study reports on a literature review of the leguminous tree *Sesbania sesban* (L.) Merr is found in the N'Djamena region, the Republic of Chad. The study focused on *S. sesban*'s medicinal and ethnomedicinal uses, biological features, and phytochemical constituents to assist in future evaluations. A literature review was conducted using academic websites, such as Science Direct and Springer, online international plant databases, and data from national herbaria. *S. sesban* is a perennial shrub or tree that measures 3–4 meters in height. This species is becoming rare in Ndjamena but can be found in the rainy season, while in winter, the species occurs mainly in ponds (called in the Chadian dialect "Bouta"), and in the shores of the Chari and Logone rivers. The local inhabitants in Chad use the species as medicine, livestock feed, fuelwood, and for improving soil fertility and repelling desert encroachment. Traditional healers use its leaves to treat breast cancer

and edema. *S. sesban* is an essential species native to the Republic of Chad that needs conservation and valorization. Viewing its importance and rarity in N'Djamena, a strategy for replanting the species in gardens, homes, and fields around Ndjamena and other regions of Chad is recommended.

Key words: Biological features, fixing-nitrogen, flora of the Republic of Chad, leguminous, medicinal and ethnomedicinal use, *Sesbania sesban*.

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Introduction

The taxonomic diversity of legumes is enormous. In addition, they provide important benefits to humans including food, medicines, and environmental services. For example, leguminous food grains include beans (*Phaseolus vulgaris* L.), peas (*Pisum sativum* L.), soya beans (*Glycine max* L.), and forage legumes such as clover (*Trifolium repens* L.), sainfoin (*Onobrychis* Mill.*)* and *S. sesban* L. Merr. These plants (leguminosae) also fix atmospheric nitrogen via their symbiotic association with soil bacteria, belonging to the genera *Rhizobium*, *Azorhizobium, Bradyrhizobium, Synorhizobium* [1]. They can be used for soil improvement [2]. Nitrogen is commonly the most limiting element in food production and one of the most expensive in fertilizers. This special ability of leguminous crops to work symbiotically with rhizobia to produce nitrogen is becoming increasingly important in world agriculture [3].

Some forage legumes such as *S. sesban* are used in agroforestry systems in tropical regions including Sub-Saharan Africa. They are also used for other purposes such as stakes, fuelwood, and reducing soil erosion. Land management practices featuring legumes include cereal-legume intercropping, relay cropping, biomass transfer, and fodder banks [4], [5], [6], [3].

Leguminous species (including *S. sesban*), also play a great role in reforestation development programs in arid areas, and the fight against desertification [7], [8], [2] They are suitable alone or mixed with other species [9].

In Africa, many indigenous species such *S. goetzei* Harms*, S. keniensis* J. B. Gillet, *S. rostrata* Bremek & Oberm, and *S. sesban* represent the genus *Sesbania.* These species and particularly *S. sesban,* possess several desirable characteristics that make them suitable for use as multipurpose trees in farming systems [10]. *S. sesban* is considered suitable to alternate and/or intercrop with other agricultural species. It grows fast and efficiently recycles available nutrients within the system, thus shortening the time required to restore fertility [11], [12].

In Chad, the genera *Sesbania* are represented by many species such as: *S. sesban*, *S. microphylla* Harms ex Phill & Hutch, *S. leptocarpa,* D.C., *S. pachycarpa,* D.C., *S. pubescens* D.C., *S. rostrata*

Brem. & Oberm., *S. sesban* (L.) var. *nubica* Chiov., *S. sesban* subsp. *punctata* D.C. & Gillett and *S. dalzielii* E. Phillips & Hutch.[13], [14]. *Sesbania* species found in Chad include *S. sesban*, *S. dalzielii*, *S. rostrata, S. leptocarpa*, *S. sericea* (Willd.) (*S. pubescens* DC), *S. hepperi* J.B. Gillett, *S. cannabina* (Retz.) Pers., *S. tetraptera* Hochst. ex-Baker, *S. pachycarpa* DC, and *S. microphylla* Harms [14].

The objective of this paper is to report medicinal and ethnomedicinal use, the biological activity and the phytochemical constituents of *S. sesban* based on a literature review. Potential uses of the species in Chad and other countries are reported in this paper. This paper contributes updated information concerning this useful but less exploited plant with the purpose to help develop and conserve it in Chad.

Materials and methods

The authors conducted a review of the literature on *S. sesban*, its applications, biochemistry, and interactions with other organisms and its environment. Sources for the review included various academic websites such as Science Direct and Springer, online international plant databases, and data from herbaria in Chad such the herbarium the Institut Supérieur de Sciences de l'Education de N'Djamena (ISSED) and the herbarium of Toumaï University (N'Djamena).

Results

Features of *S. sesban* and name

Sesbania is a Persian term and in the Arabic language is Seysaban. The original taxon was created by Antonio Jose Cavanilles (1745-1804) and modified by George Bentham in 1859 in his book *Flora brasilensis* [15]. However, the names Sesbania [16], Seseban, and Sesban already existed [15]. Related names or synonyms are *S. Sesban* var. *nubica* Chiov. [17], [5] or *S. aegyptiaca* auct. [18], [14]. The local name in Chad is "Torotoro" (in Chadian Arabic) (Ousman B. M., 2024) (unpublished). It is also called "Surridj", "Surridj-alkoubar", "Surridj-addougag" (Patrice 1997). Leonard in his botanical mission carried out on *S. sesban* in Lake Chad area in 1968 reported the local name of "Souri" to *S. sesban* (figure 4). Gaston & Fotuis [13] also reported others local names of *S. sesban* in different local Chadian dialects which are: "prepre" (in Baguirmi dialect), "sinu" (in gabri kemdé dialect), "gegelek" (in Massa-moulouhi dialect) and "dao dao" or "doo" (in Sara doba dialect). Table 1 shows the taxonomic classification of *S. sesban*.

Table 1. *S. sesban* taxonomic classification [15],[19], [20].

S. sesban Merr. (L.)	
Kingdom	Plantae
Division	Magnoliophyta or Angiosperms dicotyledonous (Flowering plants)
Tribe	Robinieae
Classe	Magnoliopsida
Order	Fabales
Family	Fabaceae
Subfamily	Papilionaceae

Gender	*Sesbania*
Species	*S. sesban* Merr. (L.)

Distribution of *S. sesban* in Africa, Chad and other countries: The genus *Sesbania* (Fabaceae or Papilionaceae) consists of about 50 species of fast-growing trees and composed of annual shrubs and perennial woody plants that are widespread in the tropics and subtropics [21], with a large number of accessions collected [10], [22]. Some 33 species are found in Africa, distributed between central and eastern Africa. *S. sesban* is widely distributed in semi-arid to subhumid regions throughout the continent [18]. It develops in the wild in most geographical zones of Africa and in many different soil types [22]. Orwa et *al.,* (2009) [6] reported that the other African countries where *S. sesban* is found in habitat are Chad, Egypt [14], Kenya, and Uganda. More recent databases on species distribution such as the Plants Of the World Online [23] and Atlas World Agroforestry (Climate Change Atlas) [24] showed that the native range of this species *S. sesban* is Tropical & South Africa, Arabian Peninsula, Indian Subcontinent. It is a shrub or tree and grows primarily in the seasonally dry tropical biome. Dufour-Dror, (2013) [25] reported that *S. sesban* Is an invasive species in Israel and the U.S. state of Hawaii [25] It has become naturalized in many of the countries where it is cultivated, and is characterized by very rapid early growth [26] (Fig. 1).

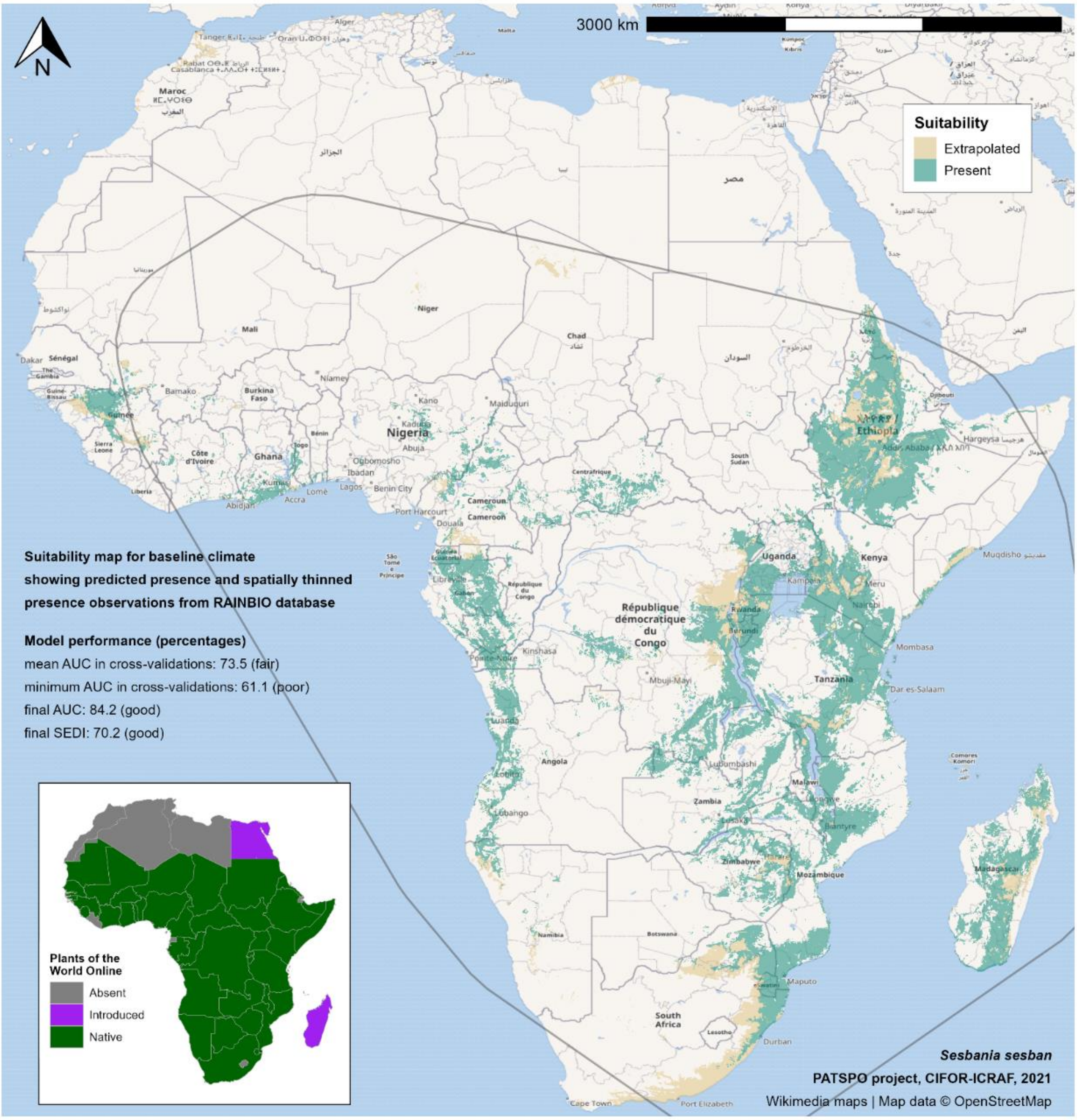

Figure 1. *S. sesban* Merr. (L.) is native in Chad and other countries [24].

In Chad, *Sesbania* species includes *S. sesban* (Fig. 2), *S. microphylla* Harms ex. Phill & Hutch, *S. leptocarpa* D.C., *S. pachycarpa* D.C., *S. pubescens* D.C., *S. rostrata* Brem. & Oberm., *S. sesban* (L.) var. *nubica* Chiov., *S. sesban subsp. punctata* D.C. & Gillett and *S. dalzielii* E. Phillips & Hutch [13], [14]. Chad is a centre of diversity for some of these species. However, *Sesbania* species have not been fully exploited as multipurpose plants in many central African countries [13]. As reported by César & Chatelain (2019) [14] and [20], *S. sesban* is found in different niches in Chad such as: on riverbanks, in stream beds, wetlands and around the water sources of Borkou and Ennedi (Fig. 2).

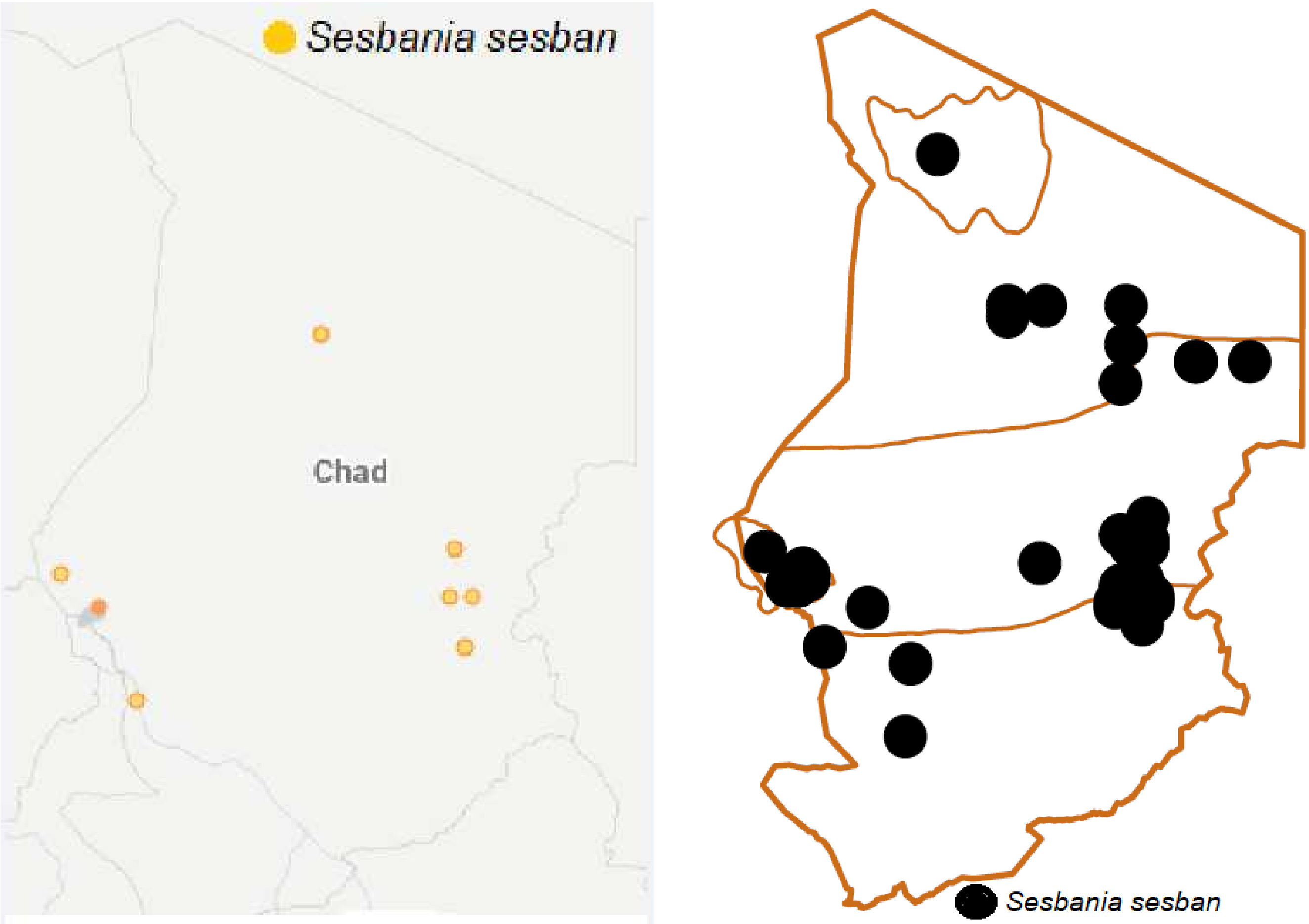

Figure 2. In orange color: zones of Chad where *S. sesban* is found [27]. In black color: zones of Chad where *S. sesban* is found according to [14].

Habitat and Ecology: Widely adapted, *S. sesban* tolerates drought, waterlogging, soil acidity, alkalinity, and salinity [28]. *S. sesban* grows well in the subtropics and in cooler, higher elevation regions of the tropics [6], [29]. It is ideally suited to seasonally flooded environments [6]. It occurs naturally in wet habitats such as lake shores, on muddy river banks and in seasonally flooded valley bottoms [5]. In Chad, *S. sesban* is becoming rare in Ndjamena but can be found in rainy season, while in winter, the species occurs mainly in ponds (called in Chadian dialect "Bouta"), and in the shores of Chari and Logone rivers (Ousman B. M., 2024) (unpublished). It also grows in open savannah [30] and, dry semi-arid zones [22] [20]. It grows in a wide variety of soils from loose, sandy soils to heavy clays [31], [32]. *S. sesban* has moderate tolerance of frost [33]. *S. sesban* grows well on acidic and infertile soils in a semi-arid region of Rwanda [34].

Biophysical limits: The mean annual growing temperature of *S. sesban* is between 18 °C and 23 °C (maximum 45 °C) and the mean annual rainfall is from 500 to 2000 mm [6], [33]. Its altitude ranges between 100 and 2500m [6], [33].

Pests and diseases: *Sesbania* spp. is attacked by nematodes, insects, fungi, and viruses [6]. The leaf-eating beetle *Mesoplatys ochroptera* can completely defoliate *S. sesban* leading to mortality. Various caterpillars, *Hymenoptera*, and stem borers attack *S. sesban.* Some potentially destructive root-knot nematodes have been recorded in India on *S. sesban* [6]. *Sesbania* is infected by mild and severe mosaic disease virus, which is transmitted by sap and roots, showing vein clearing and reduction of leaflets. The prevalence of infection of mosaic disease virus ranges from 5-20%. *Sesbania* plants grown in vitro with mild mosaic virus inoculation had fewer pods and were very small. The virus inoculated in vitro has a great tolerance of dilution (between 1000-10,000), resistance to heat (40-60°C) and has longevity in vitro varying between 10 and 14 days [35]. Sileshi et *al.* (2000) [36] conducted a survey in Southern Malawi and found that insects *Anoplocnemis curvipes*, *Aphis fabae, Hilda patruelis, Megaleurothrips sjostedti, Mylabris dicincta, Nezara viridula* and *Ootheca* spp. have the potential to become pests of *S. sesban*.

Morphological description: *S. sesban* is a soft, slightly woody, and short-lived shrub or small tree reaching 3-4m tall, broadleaved, seed propagated (Fig. 3a) [26], [20], [23], [37]; [38]; [39]; [40] [41]; (Ousman B.M., 2024) (unpublished). Partey et *al.,* (2017) [29] described *S. sesban* as a narrow-crowned, deep-rooting, single or multi-stemmed shrub or small tree, 1–5 m tall (Fig. 3a). Shun-ching (1960) [42] reported that in Taiwan, *S. sesban* measures approximately 4-5 meters in height, after six months with a diameter of up to 12cm. César & Chatelain (2019) [14] also mentioned that *S. sesban* is a tall shrub plant measuring 3–4 meters (Fig. 3a). The average diameter growth measured in basal circumference is ranging from 16-28cm. Branches have opposite pairs in a straight line, with points that look like hairs (Fig. 3b) [43]. There are at least 20 pairs of leaves that cross one by one each 180° from the previous one, and forming a cone that gradually closes (Fig. 3b, 3c) [14] [43]. These leaves are odd-pinnate with one pair of leaflets at the base having large, irregularly lobed terminal leaflets (Fig. 3b, 3c). The flowers are yellow and are arranged in clusters forming from 2 to 20 flowers and almost 20cm long. The filament sheath is 9-13 mm and yellow-purple speckled, and in rare cases, is pure yellow (Fig 3b, 3c) [14] [43].The plant is glabrescent or glabrous (Fig. 3a, 3b, 3c) [5], [14], [15]. Five to seven seedpods are grouped together in the form of grapes (Fig. 3d) [14]. seedpods are subcylindrical, light green just after formation, and yellow in color when maturing, straight or slightly curved, up to 30cm long and 5mm wide, containing 10-50 seeds (Fig. 3d) [14] [43]. A drawing seedpods and leaves are presented in figure 3e [14]. Soaking the seeds in water for a few days is sometimes required to make them germinate [15].


a


b

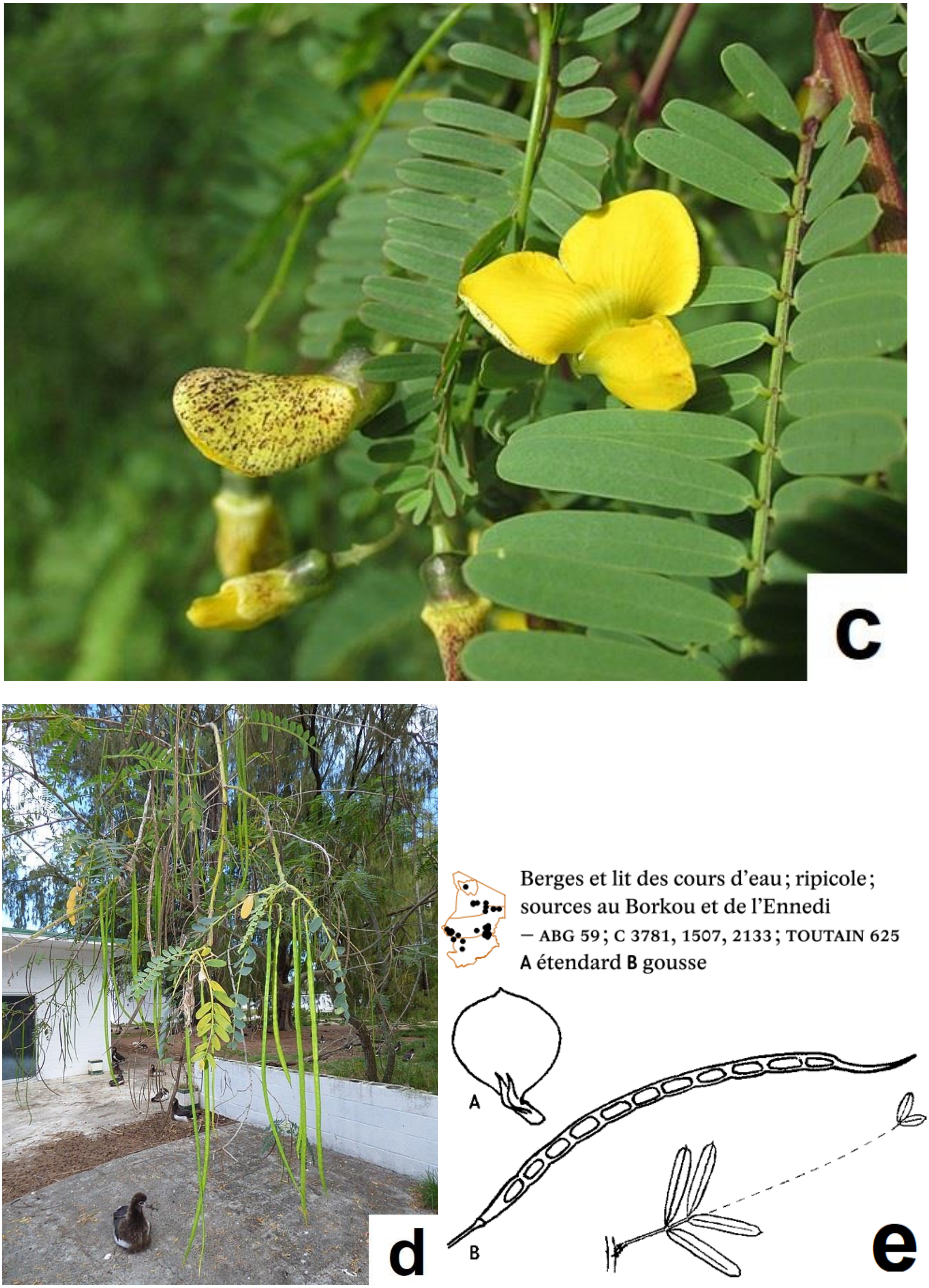

Figure 3. a: *S. sesban* tree or shrub [41]. **b:** *S. sesban* leaves and stem [43]. **c:** *S. sesban* flowers [43]. **d:** *S. sesban* seedpods [43]. **e**: Drawing of seedpods and leaves [14]

We note that the botanical missions carried out on *S. sesban* date from 1968 by the botanist Léonard [44] and from 2019 by the botanists César and Chatelain [14]. Léonard collected this species in 1968 in the region of Lake Chad [44] (Fig. 4).

Figure 4. The figure shows the botanical mission carried out on *S. sesban* in Lake Chad area by Léonard in 1968 [44].

Uses of *S. sesban*: Medicinal use, biological activity and phytochemistry

Medicinal use and biological activity: In sub-Saharan Africa, the use of plant resources for therapeutic/medicinal, agricultural, and other purposes is common, hence the need for intervention in protecting and enhancing these resources [45]. The local population in Chad is aware of the importance of the species *S. sesban* and benefits from its use for medicine, for improving land cover and soil fertility, for feeding and shading livestock and for wood [46], [47]; (Ousman B.M, 2023) (unpublished). Abdelgawad et *al.,* 2023 [48] conducted a holistic overview on *S. sesban* leaves and their phytoconstituents and pharmacological activities or effects [49] and presented that *S. sesban* leaves exhibited several therapeutic potentials such as antioxidant, antimicrobial, antiviral, anthelmintic, molluscicidal, antifertility, anti-inflammatory, antidiabetic, antihyperlipidemic, anticancer, antianxiety, and mosquito repellant properties. More detail is provided in the subsections text below.

Antioxidant activity: Mani et *al.,* (2011) [37] evaluated *the in vitro* antioxidant and antimicrobial activities of *S. sesban* leaves' ethanolic extracts. The phytochemical screening reports the presence of saponins, tannins, phenolic compounds, and flavonoids. The antioxidant activity of ethanolic extracts was demonstrated by the DPPH (Diphenyl -2-Picryl hydrazyl) radical scavenging test, which shows a remarkable scavenging activity depending on the dose of 100µg/ml. The reducing capacity increased with the increasing concentration of the sample. When the 100µg/ml ethanol extract was found, the active free radical scavenging activity increased from 16.71% (20µg/ml) to 76.25% (100µg/ml). This reducing power serves as a significant indicator of antioxidant activity.

Kathiresh et *al.,* (2012) [38] found further evidence of *S. sesban*'s antioxidant activity. They extracted anthocyanin compounds, total phenol, and flavonoids from *S. sesban* flower petals using methanol and acidified methanol extracts. The anthocyanins content confirmed by ferric chloride and aluminium chloride tests were used for analysing the antioxidant and antimicrobial properties. The total anthocyanin content obtained from the methanol and acidified methanol extracts were 0.38mg/100g and 0.28mg/100g respectively. The antioxidant activity of acidified methanol extracts using the hydrogen peroxide test showed high scavenging activity of 84% at lower concentration (1mg/ml) along with the standard butylated hydroxytoluene (37.65%).

Anti-microbial activity: Kathiresh et *al.,* (2012) [38] found further evidence of *S. sesban*'s antimicrobial activity. The antimicrobial property of *S. sesban* flower extract was explained by the zone of inhibition occurring around the wells containing different concentrating of the extracts in the the disc diffusion assay. This antimicrobial activity of the samples after 24hours showed that the zone of inhibition was found in Gram-positive bacteria (*Staphylococcus aureus* (1mg) and *Staphylococcus saprophyticus* (12.5mg)) whereas there was no inhibition in Gram-negative bacteria (*Escherichia coli Klebsiella pnemoniae Klebsiella oxytoca, Proteus vulgaris, Streptococcus pyogenes, Pseudomonas aeruginosa*, and *Enterococcus faecalis*).

Arif Ahmed et *al.,* (2013) [50] found further evidence of *S. sesban*'s antimicrobial features justifying the use of the bark to treat a number of ailments in Bangladesh. They investigated the phytochemical screening of ethanol, ether and chloroform extract of the plants bark and found the presence of carbohydrates, flavonoids, steroids, alkaloids, tannins and saponins. The antimicrobial activity using the disc diffusion assay. after 18 hours showed that the chloroform extract (at the dose of 250µg/ml and 500µg/ml) and the ethanol extract (500µg/ml) of *S. sesban* bark inhibited all bacteria used: 5 Gram-positive bacteria (*Staphylococcus epidermidis*, *Streptococcus pyogenes*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Bacillus subtilis*), 9 Gram-negative bacteria (*Shigella boydii*, *Shigella flexneri*, *Shigella sonnei*, *Shigella dysenteriae*, *Escherichia coli*, *Proteus vulgaris*, *Erwinia amylovora*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa*). In a disk diffusion assay, 250µg/ml of the ethanol extract of bark inhibited all microorganisms except *Proteus vulgaris* and *Enterococcus faecalis.* The ether extracts (both 250µg/ml and 500µg/ml) of *S. sesban* bark inhibited all microorganisms except *Proteus vulgaris*.

Anthelmintic activity: Ibrahim (1992) [51] examined the anthelmintic activity in vitro of *S. sesban* leaves (aqueous extract (0.25-50mg/ml) using the free-living rhabditid nematode, *Cuenorhabditis elegans*. A considerable amount of anthelmintic activity was demonstrated by extracts of *S. sesban* leaves (2.5 mg/ml) when the percentage mortality of *Cuenorhabditis elegans* nematodes was 30% and 96% after 2h and 6h treatments, respectively. Seed extracts introduced a percentage mortality of 5.6-25.5% at concentration levels of 0.25-50mg/ml. They concluded that *S. sesban* showed the highest anthelmintic effect upon *Cuenorhabditis elegans* survival at concentration levels 2.5 mg/mL, and the median lethal concentration LC_{50} values of *S. sesban* leaves were the most effective compared to other plant species studied. The LC_{50} attained 8.0 mg/mL at a minimum effective concentration 2.5 mg/ml.

In the study of Limsay et *al.,* (2014) [52], the hydroethanolic and aqueous leaf extracts of *S. sesban* (at a concentration of 5 and 10 mg/mL and, 30 mg/mL for hydroethanolic leaf extract and ethyl acetate fraction) were evaluated for their anthelmintic activity *in vitro*, against *Moneizia expansa* and *Paramphistomes* by a petri-dish method, with fenbendazole as the control. The methanolic extract was also evaluated in rats for its anthelmintic effect *in vitro* against two intestinal parasites *Hymenolepis diminuta* (in rats), a cestode, and *Syphacia obvelata* (in mice), a nematode, with Praziquantel and Albendazole as reference drugs. Interesting results were obtained for this anthelmintic effect with the inhibition zone of 15.17 mm against *Syphacia obvelata*-mice at the concentration dose of 30 mg/mL of hydroethanolic leaf extract, and 7.56 mm against *Moneizia expansa* at the concentration dose of 5 mg/ml of aqueous leaf extract [53] [54] .

Numerous studies across the world have shown that *S. sesban* has considerable potential for combatting disease and improving health. Kamel et *al.,* (2011) [55] reported that the administration of *S. sesban* leaves' methanol extract to infected mice exhibited a moderate antischistosomal effect (against the parasite *Schistosoma mansoni* which infected mice). The results suggest that the administration of *S. sesban* has antischistosomal properties, hence ameliorating liver function.

Anti-bacterial activity: Mythili & Ravindhran (2012) [39] observed the presence of alkaloids, flavonoids, phenols, and phytosterols, fixed oil and gum in the phytochemical analysis of methanol and ethanol extracts from *S. sesban* in India. The authors tested the biological screening effects of *S. sesban* methanol stem extract against ten bacterial species (Gram+ pathogens: *Staphylococcus aureus* (ATCC 25923), *Enterococcus faecalis* (ATCC 29212), Escherichia coli (ATCC 25922), Bacillus subtilis (ATCC 441), and Gram- pathogens: *Salmonella typhi* (MTCC 733), *Erwinia amylovora* (MTCC 2760), *Proteus vulgaris* (MTCC 1771), *Pseudomonas aeruginosa* (MTCC 424), *Klebsiella pneumoniae* (ATCC 15380), *Shigella dysenteriae* (MTCC 5151)). The results showed highly significant activity against the bacteria *Erwinia amylovora* with 17.25 mm in diameter followed by Escherichia coli with 16 mm in diameter at 250 µg/ml of the extract. In most of the bacteria examined, a better zone of inhibition was obtained at 250µg/ml and 500 µg/ml of the extract. When compared to the standard flavonoid quercetin, the plant extract showed a substantial amount of inhibition in the case of *Bacillus subtilis* (15.5 mm) (500 µg/ml), *Escherichia coli* (16 mm) (250 µg/ml), *Enterococcus faecalis* (12.75 mm) (250 µg/ml), *Erwinia amylovora* (17.25mm) (250 µg/ml) and *Shigella dysenteriae* (10.25 mm) (500 µg/ml).

In Sudanese folk medicine, the leaves and fruit of *S. sesban* were found to treat sore throat and gonorrhoea in the study of Elegami et *al.,* (2001) [56]. They investigated that leaves and fruit of *S. sesban* have antibacterial activity. They found that methanol extracts at the concentration dose of 100 mg/ml (0.1 ml/cup) were effective against pathogens bacteria used namely *Bacillus subtilis NCTC 8236, Staphylococcus aureus NCTC 6447, Escherichia coli NCTC 8196* and *Pseudomonas aeruginosa NCTC 6750*.

Anti-fungal activity: Mythili & Ravindhran (2012) [39] tested the biological screening effects of *S. sesban* methanol stem extract against five infectious fungal species (*Aspergillus fumigatus*, *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Fusarium oxysporum* and *Verticillium glaucum*) using the disc diffusion assay. The fungi *Curvularia lunata* and *Fusarium oxysporum* were inhibited completely by *S. sesban* methanol stem extract at the dose of 100µg/ml and 500 µg/ml. *Aspergillus fumigatus*, *Curvularia lunata*, and *Verticillium glaucum* a higher degree of inhibition was obtained with the dose 500 µg/ml. They concluded that the stem extracts of *S. sesban* possess a broad spectrum of activity against common bacterial and fungal diseases in the region of Coimbatore in India.

Arif Ahmed et *al.,* (2013) [50] evaluated the anti-fungal activity of *S. sesban* bark against 7 fungi, *Trichophyton rubrum*, *Microsporum fulvum*, *Candida albicans*, *Curvularia lunata*, *Aspergillus fumigatus*, *Fusarium oxysporum* and *Sacharomyces cerevacae*) using the disc diffusion assay. The result showed that the highest zone of inhibition was 14.2 mm against *Fusarium oxysporum*. Minimum inhibitory concentration (MIC) of these extracts was determined by broth macro dilution assay. After 12 hours, the MIC of the extracts (ethanol, ether, and chloroform) was obtained at a higher concentration (8000µg/ml) than the extract content in the disc (250µg/ml and 500µg/ml).

Anti-inflammatory activity: In India, many people use *S. sesban* leaves to relieve rheumatic pain and the biochemical evidence supporting this is clear [40]. Crude saponins (containing triterpenoids and steroids) extracted from *S. sesban* leaves showed an anti-inflammatory effect on experimental-induced rats and mice [40]. Rats pretreated with saponins significantly decreased ($p<0.01$) the carrageenan-induced paw edema by 59% at a higher dose of 500 mg/kg, 3h after the injection of noxious agent. Rats pretreated with saponins significantly inhibited ($p<0.01$) the histamine induced rat paw edema by 38.41 and 43.02% at the dose of 250 and 500mg/kg, respectively. The test of cotton pellet granuloma in rats showed that saponins (500mg/kg) inhibited the formation of fibroblast by 38.17% which was comparable with that of standard diclofenac sodium (44.32%). In the oxazolone induced delayed hypersensitivity test, saponins (500mg/kg) showed maximum inhibition (69.68% after 22days) of ear edema comparable to the standard drug which gave 73% inhibition after 22days. Saponins therefore showed significant activity in the acute phase of inflammation in the *in vivo* and *in vitro* model at the oral dose of 500mg/kg body rats' weight when compared to the control and standard drug.

Similarly, Shaikh et *al.,* (2012) [31] evaluated the anti-inflammatory activity of *S. sesban* leaf extracts of petroleum ether (60-800), chloroform and methanol. The acute toxicity study of extracts of leaves of *S sesban* showed 50% mortality at a dose (2500 mg/kg). Hence 1/10th of the same dose for all these extracts was taken as a therapeutic dose i.e., 250mg/kg. The methanolic extract showed a significant anti-inflammatory activity reducing paw edema (the dose of 250mg/kg administrated reduced 45.34% of the reduction within three hours) compared to the control group, carrageenin and Ibuprofen. Petroleum ether (60-80°) extract and chloroform extract showed comparatively less reduction in paw edema volume. The thin layer chromatography using solvent system Toluene: Chloroform: Methanol (1:1:0.8) followed by the column chromatography for separation and isolation of the constituents of the methanolic extract showed three separated constituents. Constituent I (fluorescent green colour), Constituent ii (pink colour) and Constituent III (fluorescent green colour). Constituent II showed significant reduction in paw edema (at the dose of 250mg/kg) meaning significant anti-inflammatory activity after three hours (with a percentage of 54.06) as compared to standard. The preliminary phytochemical investigation *S. sesban* extracts showed the presence of the following active principles: sterols, saponins, flavonoids in methanol extracts; fats and oil in petroleum ether (60-80°) extracts; and sterols, alkaloids, flavonoids in chloroform extracts. The study did not show any approximate percentage while it showed simply the presence or absence of these active principles obtained.

Arif Ahmed et *al.,* (2013) [50] found further evidence of *S. sesban*'s cytotoxic features, The cytotoxicity activity was investigated by the brine shrimp lethality bioassay to determine the percent mortality nauplii caused by the test extracts. The LC_{50} (lethal concentration in half) values of ethanol, ether, and chloroform extracts of bark were found to be 1280, 640, and 320µg/ml, respectivelyl after 24 hours.

Antidiabetic activiy: Pandhare et *al.,* (2011) [57] evaluated the aqueous leaf extract of *S. sesban* for its antidiabetic potential on normal and streptozotocin (STZ)-induced diabetic rats. The doses of 250 and 500mg/kg body weight per day for 30 days were administered to normal and streptozotocin-induced diabetic rats. The aqueous leaf extract administrated (250 and 500mg/kg/day) to streptozotocin induced diabetic rats (compared to the antidiabetic drug glibenclamide (0.25mg/kg body weight) indicated significant increase in the body weight, liver glycogen, serum insulin and high-density lipoproteins cholesterol levels and decrease in blood glucose, glycosylated haemoglobin, total cholesterol and serum triglycerides. Finally, the study concluded that the aqueous leaf extract of *S. sesban* has beneficial effects in reducing elevated blood glucose levels and the lipid profile of streptozotocin-induced diabetic rats, but has no effect on normal rats.

Manjusha et *al.,* (2012) [58] found that *S. sesban* roots extract may have a hypoglycaemic potential for treating type 2- diabetes. Their results show that the doses (250, 500, and 1000mg/kg) of *S. sesban* roots extract administered orally to normal and streptozotocin (STZ) induced type- 2 diabetic mice caused a marked decrease of fasting blood glucose in STZ induced type -2 diabetic mice. *S. sesban* roots extract decreased the cholesterol, triglyceride, urea, and creatinine levels and increased insulin, high density lipoproteins, cholesterol, and total protein levels.

Antinociceptive activity (analgesic): Nirmal et *al.,* (2012) [59] investigated wood's antinociceptive agents that are compounds capable of diminishing pain without negative effects on consciousness or without producing anaesthesia [60]. The anti-nociceptive activity was determined by hot plate and acetic acid induced tests. Doses were selected on the basis of a toxicity study and mice were divided into 18groups of 6animals each. The experiment was terminated 20seconds after their placement on the hot plate to avoid damage to the paws. Petroleum ether, chloroform, and ethyl acetate extracts (50 and 100mg/kg) showed significant results just 30minutes after treatment while their action was blocked by the opioid antagonist, naloxone (1 mg/kg). The involvement of opioid receptors (transmembrane neurotransmitters) was revealed by giving the extracts after an opioid antagonist (naloxone) (1mg/kg). The mechanism of the analgesic effect of the extracts of *S. sesban* wood could probably be due to blockage of the effect or release of endogenous substances that excite pain nerve endings [59]. They concluded that petroleum ether, chloroform, and ethyl acetate extracts of wood showed potent antinociceptive activity while naloxone blocked the antinociceptive activity of the extracts by inducing opioid receptors.

Control of fertility: Some studies suggest that *S. sesban* may have potential as an ingredient of contraceptives. Shiv (1990) [61] studied the effect of *S. sesban* seed powder in female albino rats to evaluate its effects on genital organs and fertility. In the results, rats of the control group did not show any change in body weight and genital organ weight. The dose 100mg/kg for 30 days of administration caused no deleterious effect on ovarian tissues, whereas the 250mg/kg dose severally affected the ovarian structure, mature follicles underwent atresia, some developing follicles showed lysis of ova and the stroma was compact with poor vascularity. However, the genital organ weight was reduced significantly ($P<0.05$) after the treatment at 250 and 400mg/kg/day doses for 30days. The dose 250mg/kg reduced endometrial height and size of the uterine glands. The administration of 400mg/kg for 30days caused a great reduction in endometrial height, uterine glands. The control group of rats showed normal fertility; all became pregnant and showed a good number of implants, whereas the dose 100mg/kg dose showed pregnancy and reduction of implants. The doses 250 and 400mg/kg showed 100% antifertility activity and no implants were recorded in the uterus of these rats on the 10th day of pregnancy. The experiment showed that *S. sesban* seed powder inhibits ovarian function, changes the uterine structure, and prevents implantation and, thus, controls the fertility of female albino rats [61].

In another study, Nilanjana et *al.,* (2011) [62] isolated from *S. sesban* roots extracts an active principle oleanolic acid 3-beta-D-glucuronide (OAG) which is suggested to have a potent spermicidal activity. In the experiment, the dose of the minimum effective concentration (MEC) of OAG was 50mcg/mL after one hour of the treatment and, induced 100% immobilization of the sperm. More than 97% of the OAG-treated sperm lost their hypo-osmotic swelling responsiveness in a dose-dependent manner. The transmission electron microscopy and sperm membrane lipid peroxidation revealed that OAG affected the sperm membrane integrity. All observations in the experiment clearly demonstrated that OAG has very strong antifertility activity and other properties that qualify the agent to serve as an active ingredient of vaginal contraceptives [62].

Central nervous system stimulant: The aqueous extract of *S. sesban* bark has a potential central nervous system (CNS) stimulant effect [63]. The investigation of CNS stimulant activity was carried out on albino mice and caffeine was used as a reference drug. The animals receiving the treatment were divided into three groups: Group I served as control and treated orally with vehicle (normal saline), Group II served as standard, and caffeine 30mg/kg was given, and Group III received aqueous extract of *S. sesban* bark at the dose of 400mg/kg. In the elevated plus maze experiment, the animals received the treatment 45min before the start of session. At the beginning of the session, a mouse was placed at the centre of the maze, its head facing the closed arm. It was allowed to explore the maze for 5 minutes. The time spent in the open arms, percent entries in the open and closed arms, and total entries were recorded. An entry was defined as the presence of all four paws in the arm. Naik et *al.,* (2011) [63].concluded that the crude aqueous extract at the dose of 400mg/kg after 48 hours showed significant central nervous system CNS stimulant activity in comparison to the control group and the results were comparable to the activity shown by the reference drug. Table 2 summarizes *S. sesban's* medicinal use, the biological activity, the plant parts used and optimal solvents; the dosage regimen and its corresponding concentrations and the active constituents.

Molluscicidal activity: *S. sesban* leave extracts showed molluscicidal activity. In the study of [64], the effects of sublethal concentrations of methanol extract of *S. sesban* leaves on survival rate, egg laying of *Bulinus truncatus* snails, hatchability of their eggs, infection rate with *Schistosoma haematobium* miracidia, cercarial production and certain physiological parameters of treated snails were studied. In the results, after 24 hours of exposure, the sublethal concentrations of the tested plant extract (LC_0=1.8ppm, LC_{10}=8ppm, LC_{25}=14, LC_{50}=18ppm and LC_{90}=31ppm) caused considerable reduction in survival rates; egg production of *Bulinus truncatus* snails; hatchability of eggs as well as in the infectivity of *Schistosoma haematobium* miracidia to the snail. The longevity of *Bulinus truncatus* snails exposed continuously to sublethal concentrations of methanol extract of *S. sesban* decreased from LC_0=22.5±6.2 days to LC_{10}= 11.8±4.2. The death rate of *Bulinus truncatus* snails in groups treated with LC_0 was highly significant as compared with those in groups treated with LC_{10} and LC_{25} ($p < 0.01$). A reducing of the cercarial production per snail and the period of cercarial shedding was also observed. Glycogen level, protein content and the activities of hexokinase (HK), pyruvatekinase (PK) and lactate dehydrogenase (LDH) showed a decrease in soft tissues when compared with the control group. They concluded that the application of sublethal concentration of methanol extracts of *S. sesban* leaves may be helpful in snail control as it interferes with the snails' biology and physiology.

Furthermore, in the study of [65], the molluscicidal activity against snail species *Biomphalaria alexandrina* infected with *Schistosoma mansoni* was investigated. *Biomphalaria alexandrina* species was treated with aqueous extracts of *S. sesban* leaves. The extracts significantly lowered the infection rate of the snail. Exposure of snails for 4 weeks to LC_{10} and LC_{25} of S*. sesban* leaves (dry powder) considerably suppressed their fecundity and the reproduction rate. The reduction rate of reproduction for the exposed snail to LC_{25} of *S. sesban* was 76.4%. infection rates of snails treated during miracidial exposure with LC_{10} of *S. sesban* was 52.2% compared to 92.6% for control group ($P < 0.01$). Snails exposed to LC_{25} of *S. sesban* leaves extracts showed a reduction of the duration of cercarial shedding and cercarial production/snail with a value of 223.2 cercariae/snail compared to 766.3 cercariae/infected control snail ($P < 0.01$). It is concluded that LC_{25} of *S. sesban* leaves aqueous extracts negatively interferes with biological and physiological activities of *Biomphalaria alexandrina* snails, consequently it could be effective in interrupting and minimizing the transmission of *Schistosoma mansoni* [65]. Saponins are some of the secondary metabolites that are synthesized by many plants [66]. Molluscicidal activity of *S. sesban* can be attributed to saponins whose mode of action is believed to cause cell membrane rapture causing water and ions to flow uncontrollably into and out of the cell. This causes the cell to lose integrity leading to death of the snails [49].

Table 2. Medicinal use, biological activity, plant parts used, dosage regimen and its corresponding concentrations and active constituents of *S. sesban*.

	Biological activity	Plant part used and optimal solvents	Dosage regimen and corresponding concentrations	Active constituents	References
Medicinal use	Antioxidant activity	Leaves, seeds (ethanolic and methanol extracts)	100µg/ml after one and half hour 1mg/ml after one and half hour	Saponins, flavonoids, anthocyanins	[37] [38]
	Anti-microbial activity	Flower petals (methanol and acidified methanol)	1mg -12.5mg/ml after 24 hours	Anthocyanins	[38]
	Antimicrobial activity	Bark (ethanol, diethyl ether, chloroform)	250µg-500µg:ml after 18 hours 250-8000 µg/ml for the MIC after 12 hours	Carbohydrates, flavonoids, steroids, alkaloids, tannins, saponins	[50]
	Anthelmintic activity	Leaves, seed (aqueous extracts) Leaf (Hydroethanolic and aqueous extracts)	2.5 mg/ml after 6 hours 5 and 10 mg/mL	Saponins, glycosides Saponin, flavonoids, betulinic and ursolic acids	[51] [52] [54] [53]
	Antischistosomal effect against the parasite *Schistosoma mansoni* infected the mice	Leaf powder	1000 mg/kg/day for 9 weeks post infection (PI)	Methanol extract	[55]
	S. sesban has highly significant antibacterial and antifungal activity	Stem (methanol extracts)	250µg/ml and 500 µg/ml for bacteria at 37ºC after overnight. 100µg/ml and 500 µg/ml for fungi at 28±2°C after 48 hou	Carbon tetrachloride partitionate, alkaloids, flavonoids, tannins, phytosterols	[39]
	Cytotoxic activity	Bark (ethanol, diethyl ether, chloroform)	320-1280 µg/ml after 24 hours	Carbohydrates, flavonoids, steroids, alkaloids, tannins, saponins	[50]
	Anti-inflammatory activity	Leaves (methanol)	500 mg/kg after 3 hours until 22 days. 250mg/kg after 3 hours	Saponins	[40] [31]

	Antidiabetic activity	Leaves (aqueous extracts)	250 and 500mg/kg after day	Triterpenoids, tannins, saponins, glycosides, steroids	[57]
	S. sesban roots extract exhibited significant antihyperglycemic activities in streptozotocin STZ-induced diabetic mice	Roots (Petroleum ether extract)	200-1000mg/kg after 2hours and blood samples were withdrawn until 15 days	Phytosterols, fixed oils fats, saponins, proteins, gums, mucilage and amino acids	[58]
	Antinociceptive activity (analgesic)	Wood (petroleum ether, chloroform, ethyl acetate)	50 and 100mg/kg after 30 minutes	Sterols, triterpenes, flavonoids	[59]
Medicinal use	Control the fertility of female albino rats	Seeds (distilled water)	250 and 400 mg/kg/ for 30 days	-	[61]
	Potent spermicidal activi	Roots (ethylacetate, n-butanol saturated, ethanol, water)	50 mcg/ml after one hour	Oleanolic acid3- beta-d-Glucuronide	[62]
	Central nervous system stimulant	Bark (aqueous extract)	400mg/kg after 48hours	Carbohydrate, alkaloids, phytosterols	[63]
	Molluscicidal activity	Leaves (methanol and aqueous extracts)	LC_0=1.8ppm to LC_{90}=31ppm after 24 hours for aqueous extracts. LC_0=5.11pm to LC_{90}=62.4ppm after 4 weeks for aqueous extracts.	Saponins	[64], [65]
	Antioxidant, antimicrobial, antiviral, anthelmintic, molluscicidal, antifertility, anti-inflammatory, antidiabetic, antihyperlipidemic, anticancer, antianxiety, mosquito repellent properties	Leaves	-	steroids, triterpenoids, saponins, flavonoids, coumarins, lipids, and other miscellaneous compounds.	[48], [49]

Phytochemistry of *S. sesban*: *S. sesban* has different chemical compounds that are, once extracted, very useful for treating diseases such antibacterial, antioxidant agents, for manufacturing drugs, organic or chemical supplements. They are also useful for manufacturing biological manure [67], [38]. The phytochemical screening test of different leaf extracts of *S. sesban* (Methanol, Chloroform, and Petroleum ether (60-80°)) in the study of [31] revealed the presence of sterols, saponins, flavonoids. alkaloids, fats and oil, proteins, sterols, anthraquinone glycosides, gums and miscellaneous compounds. Carbohydrates, vitamins, amino acids, tannins and saponin glycosides are also detected in the screening test of the aqueous extracts in the study of [57]. Arif Ahmed et *al.,* (2013) [50] studied the chemical screening of *S. sesban* bark and the results indicated the presence of carbohydrates, flavonoids, steroids, alkaloids, tannins and saponins in the ethanol, ether (diethyl ether) and chloroform extracts (95% each one).

Samajdar & Ghosh, (2017) [68] reported from different studies that the preliminary phytochemical screening of *S. sesban* uncovered the presence of triterpenoids, starches, vitamins, amino acids, proteins, tannins, saponins glycosides and steroids. Blossoms contain cyanidin and delphinidin glucosides. Dust and dust tubes contain alpha- ketoglutaric, oxaloacetic and pyruvic acids. Leaf and unit contain campesterol cholesterol, beta-sitosterol, triterpenoids, proteins and tannins. Bark and stem contain glucose, fructose, erythritol, arabinitol, myo-inositol. Different sorts of lignin made out of guaiacyl, syringyl and P-hydroxyphenylpropane building units and furthermore antitumor vital kampferol disaccharide [69], [68], [70]. Sterols and triterpenes are detected in petroleum ether and chloroform extracts of *S. sesban* wood, and flavonoids in ethyl acetate extract in the study of [59]. carbohydrates, alkaloids, phytosterols, saponins glycosides, and phenolic compounds are detected in petroleum ether chloroform and aqueous extracts of *S. Sesban* bark [63]. In the study of [39], the phytochemical analysis of the methanol and ethanol extracts of both stem and root of *S. sesban* revealed the presence of alkaloids, carbohydrates, proteins, phytosterol, phenol, flavonoids, fixed oil and gum. The leaf extract showed the presence of alkaloids, carbohydrates, protein, phytosterol, flavonoids and fixed oil.

Leaves of *S. sesban* are used as supplementation on growth and reproduction performance for 30 male Ethiopian highland sheep and 25 East African goats [71]. In this study, many chemical compositions in *S. sesban*' leaves for the feed ingredient were detected among them dry matter, crude protein, gas production, ash, neutral detergent fibre, acid detergent fibre, neutral detergent fibre bound nitrogen, soluble proanthocyanidins, quercetin, and saponin [72] [71]. Anthocyanins, phenols, flavonoids are identified in methanol and acidified methanol extracts of *S. sesban* flower petals [38]. The oleanolic acid 3-β-D-glucuronide has been isolated and evaluated from the root extracts of *S. sesban* [62]. In the chemical study of Abdelgawad et *al.,* 2023 [48], many phytochemical compounds of *S. sesban* leaves was presented and have a variety of essential metabolites belonging to different chemical classes including steroids, triterpenoids, saponins, flavonoids, coumarins, lipids, and other miscellaneous compounds. Details of phytochemical compounds extracted from part of the species *S. sesban* with the extraction solvent are shown in Table 3.

Table 3. *S. sesban*: phytochemical compounds, parts used for extraction, and their extraction solvent.

Phytochemicals compounds	Part used for extraction	Extraction solvent	References
Sterols, saponins, flavonoids. Alkaloids, fats and oil, proteins, sterols, anthraquinone glycosides, gums, miscellaneous compounds	Leaves	Methanol, Chloroform, Petroleum ether 60-80°	[31]
Triterpenoids, carbohydrates, vitamins, amino acids, proteins, tannins, saponin glycosides, steroids	Leaves	Aqueous extracts	[57]
Carbohydrates, flavonoids, steroids, alkaloids, tannins and saponins	Bark	Ethanol Ether (diethyl ether) Chloroform	[50]
-Cyanidin and delphinidin glucosides. -Alpha- ketoglutaric, oxaloacetic and pyruvic acids. -Campesterol cholesterol, beta-sitosterol, triterpenoids, proteins and tannins. -Glucose, fructose, erythritol, arabinitol, myo-inositol. -Guaiacyl, syringyl and p-hydroxyphenylpropane, kampferol disaccharide.	-Blossoms. -Dust (pollen) and dust tubes. -Leaf and pods -Bark and stem. -Lignin.	Aqueous extracts	[68], [69], [70]
Sterols, triterpenes. flavonoids	Wood	Petroleum ether and chloroform Ethyl acetate	[59]
Carbohydrates, alkaloids, phytosterols, saponins glycosides, phenolic compounds	Bark	Petroleum ether, chloroform and aqueous extracts	[63]
Alkaloids, carbohydrates, proteins, phytosterol, phenol, flavonoids, fixed oil and gum	Stem, roots and leaf	Methanol, ethanol	[39]
Dry matter, crude protein, gas production, ash, neutral detergent fibre, acid detergent fibre, neutral detergent fibre bound nitrogen, soluble proanthocyanidins, quercetin, saponin,	Leaves	-	[72] [71]

Anthocyanins, phenols, flavonoids	Flower	Methanol and acidified methanol	[38]
Oleanolic acid 3-β-D-glucuronide	Root	Ethyl acetate and n-butanol saturated extracts	[62]
Steroids, triterpenoids, saponins, flavonoids, coumarins, lipids, and other miscellaneous compounds	Leaves	-	[48]

Ethnomedicinal uses of *S. sesban*:

Treating breast cancer, oedemas and wounds: Healers in Chad use the leaves and bark of *S. sesban* alone to treat breast cancer, oedemas and wounds. Breast cancer is treated in traditional medicine by macerating the leaves for 48 hours or using an infusion of root and bark. After macerating the leaves, the juice obtained is drunk in the morning and evening. To treat edema and swollen glands, the leaf powder is mixed with oil and then applied to the body until cure. In Chad, traditional healers often sell *S. sesban* formulations from leaves and bark to patients in the form of syrup or powder to treat breast cancer, oedema and wounds as the same manner of previous use. Healers sold such medicine about 360 times per year, earning an average of $1.74 per sale. Annual revenue thus amounted to about $US 625$/year (Ousman B. M., 2024) (unpublished).

Treating livestock diseases: *S. sesban* is also used in treating livestock diseases. Harun-or-Rashid et *al.,* (2010) [73] reported that the leaves of *S. sesban* are used in Bangladesh for the treatment of cattle diseases. The leaves are administered orally to treat the retention of urine of cows, goats, and buffaloes. Similarly, Rahmatullah et *al.,* (2010) [74] conducted an ethnoveterinary survey among selected villages of Bagerhat district in Bangladesh and documented that *S. sesban* leaves and stem are used topically to treat pain arising out of pox of cattle. The leaves are dried in sunlight and then spread over the bodies of cows, goats, or buffaloes. At the same time, the bodies of cows, goats, or buffaloes are brushed with stems and leaves [74]. Sori et *al.,* (2004) [75] reported that pastoralists of Borana district in the Southern Ethiopia use *S. sesban* root and bark to treat mastitis in order to control the disease of the livestock. The Infusion of root and bark are topically used for the treatment of mastitis.

Treating malaria: Chinsembu (2015) [76] in Zambia and Rasoanaivo et *al.,* (1992) [77] in Madagascar reported respectively that the vapor of *S. sesban* leaves obtained from boiling is inhaled two times a day for three days, and a drinking decoction of aerial parts used to cure malaria.

Mosquito repellant: Samajdar & Ghosh (2017) [68] reported that *S. sesban* leaves are used as mosquito repellent in India for livestock. The preparation method is to wash the bodies of animals with water leaf extracts until cure [68]. The leaf decoction is used for cattle drench to repel tsetse flies in India [68].

Demulcent, anthelmintic, purgative, anti-inflammatory and treating eczema: Abdelgawad et *al.,* (2023) [48] mentioned that *S. sesban* leaves have been traditionally used as an anthelmintic, demulcent, purgative, and anti-inflammatory agent in the treatment of eczema, in addition to its agricultural uses. Table 4 shows the ethnomedicinal use of *S. sesban*, plant part used, dosage regimen and mode of preparation.

Table 4. Ethnomedicinal use of *S. sesban*, plant part used, dosage regimen and mode of preparation.

	Disease treated	Plant part used	Mode of preparation	Dosage regimen	References
Ethnomedicinal use	Breast cancer:	Leaves, bark, roots	Maceration of leaves for 48 hours or infusion of root and bark.	Drink the maceration morning and evening	(Ousman B. M., 2024) (unpublished)
	Oedema and swollen glands	Leaves	Leaf powder and oil were applied to the body	Apply to the body until cure	
	The retention of urine of cattle (cows, goats, and buffaloes)	Leaves	Fresh leaves and stems administrated orally	-	[73]
	Pain arising out of pox of cattle	Leaves and stem	The leaves are dried in sunlight and then spread over the bodies		[73]
	Treating mastitis of livestock	Root and bark	The Infusion is topically used	Apply to the body until cure	[75]
	Antimalarial	Leaves and aerial parts	The vapour from boiling leaves is inhaled or a decoction of the parts is drunk	Inhaling vapour two times a day for three days	[76] [77]
	Mosquito repellant	Leaves	Wash the bodies of animals with water leaf extracts	Wash the body until cure	[68]
	Repel tsetse flies	Leaves	Leaf decoction is drenched	Until cure	
	Demulcent, anthelmintic purgative, and anti-inflammatory agent in the treatment of eczema	Leaves	-	-	[48]

S. sesban use for soil improvement in agriculture and in cropping systems

Land degradation and declining soil fertility are critical problems impacting livelihoods in many parts of Africa [3].

Induces root nodules of *Rhizobuim* strains and fixes nitrogen on the soil to improve it: In Chad, the local population uses *S. sesban* to enrich soil fertility of the cited soils for increasing yields of crops such as *Oryza* sativa L., *Zea mays* L., *Sorghum bicolor* L., *Cenchrus americanus* (Pearl millet) (Ousman B. M., 2024) (unpublished).

In México, Bashan et *al.,* (2012) [8] have demonstrated that native leguminous trees such *S. sesban* are essential to ensure the revegetation of eroded desert lands and restoration of severely eroded soil by fixing nitrogen, resisting salt and drought and producing high biomass under desert conditions at the southern limit of the Sonoran desert in agricultural and agroforestry systems. The population plants the leguminous trees such as *S. sesban*, *Prosopis articulata, Parkinsonia microphylla* and *Parkinsonia florida* and inoculates with growth promoting bacteria *Azospirillum brasilense*, *Bacillus pumilus*, a native fungus arbuscular mycorrhizal (AM), and small quantities of compost. A high density of these leguminous trees with shrub and trees was obtained in these severely eroded soil areas with a remarkable degree of revegetation and more stabilized soil with a high volume of organic matter.

Samajdar & Ghosh (2017) [68] mentioned that *S. sesban* is appreciated for its nitrogen fixing quantities and as a windbreak on farms in India.

Abbas et *al.,* (2001 [22] found in Egypt that *S. sesban* intercropped with some annual grasses (barley, pearl millet, and Rhodes-rye and Sudan-grasses) and inoculated with rhizobia improved the quality and quantity of field forage crops. They also found that intercropping improved productivity of non-legumes, in particular barley mixed with the legume *S. sesban* and the calculated N-transfer from legumes to non-legumes ranged from 20 to 70kg N/ha. They concluded that intercropping of forage grasses with legumes is economic and has a high environmental return under the semiarid conditions of Egypt and that *S. sesban* performs better when intercropped with Sudan grass.

Sobere (1991) [78], Bala et *al.,* (2002) [79], and Sharma et *al.,* (2005) [80] reported in the same way that *Rhizobuim* strains induce root nodules and fix nitrogen from the air in symbiosis with *S. sesban.*

Curasson (1956) [7] and Rochester et *al.* (2001) [81] reported that *S. sesban* is cultivated in rotation with cotton in Sudan and Australia and it may enhance soil fertility and improve soil conditions. *S. sesban* yields are reported to range from 28 to 35 tons/hectare after three years of growth [7].

Balaisubramanian & Sekayange (1992) [34] reported on an experiment in a semi-arid site in Rwanda with *S. sesban* grown as a hedge spaced 5 meters apart in cultivation with beans (*Phaseolus vulgaris* L.), sorghum (*Sorghum bicolor* L.), maize (*Zea mays* L.) and sweet potato (*Ipomoea batatas* L.), The produced foliar biomass was 1.78 and 0.59t/hectare respectively for 1983/84 and 1985/86. The wood produced was 0.27 and 0.28 t/hectare for 1983/84 and 1985/86, respectively. In addition, it allowed the production of nutrients for the soil of 25.6 kg of nitrogen/ha, 1.4 kg of phosphate/ha, 14 kg of potassium/ha, 16.2 kg of calcium/ha and 4.4 kg of magnesium/ha, significantly improving soil fertility. Other studies have found that *S. sesban* improves soil fertility. Bakhoum et *al.,* (2018) [82] reported that planting nitrogen-fixing trees such as *S. sesban* is an effective in increasing soil productivity. Nigussie & Getachew (2013) [83] and Degefu et *al.,* (2011) [18] reported that *S. sesban* has the ability to restore eroded soil by fixing nitrogen in the soil. Mengistu et *al.,* (2002) [84] reported on the use of

S. sesban as green manure in Ethiopia. *S. sesban* biomass decomposes rapidly due to the soft plant structure and high N content, and it provides nutrients to the soil and other plants. It is used for improvement of fallows, mixed cropping, relay cropping, and biomass transfer [85]. *S. sesban* helps restore and enhance soil fertility by drawing up nutrients from lower soil layers and then adds nutrients to the soil in litter fall [85] .

Sontosh et *al.,* (2017) [86] harvested the biomass of *S. sesban* accessions 20 days after sowing and used it as a green manure crop in a rotation of Rice-Rice-Mustard. They demonstrated that *S. sesban* can be grown and harvested over a very short period and still be useful for adding organic matter to the soil. They also pointed out that the decomposability, organic matter accumulation, and N2-fixing ability of *S. sesban* biomass make it a suitable cultivar for poor, nutrient-deficit soils [87].

In intercropping and alley cropping, agricultural crops are grown simultaneously with a long-term tree crop to provide annual income while the tree crop matures. Muimba-Kankolongo (2018b) [88] reported that intercropping sweet potato with *S. sesban* improves yield of the crop. In the same way, intercropping *S. sesban* with rice and annual grasses in semi-arid conditions helps manage weeds and optimize the yield of dry-seeded rice [22], [89]. Singh et *al.,* (2007) [89] concluded that application of wheat residue mulch at 4t/ha and *S. sesban* intercropped for 30 days were equally effective in controlling weeds associated with dry-seeded rice. Economic analysis showed that *S. sesban* was as effective as mulch in realising higher economic returns for dry-seeded rice yields during 2003 and 2004.

S. sesban also has considerable potential in saline environments where many plants cannot grow. In southern Morocco, agriculture systems are limited by the lack of water resources and salinization of surface and underground freshwater sources. The National Institute of Agronomic Research (INRA) has become interested in the adaptation of *S. sesban* to saline environments and its contribution to improving food and fodder production in desert areas. INRA scientists have successfully introduced *S. sesban* in a saline environment for these purposes in the region of Laâyoune [90]. Bala et *al.,* (1990) [91] found also that biological nitrogen fixation can be significantly increased by inoculating tree legumes such *S. sesban* with salinity-tolerant rhizobia under saline conditions.

Tolerates high salinity soil (up to 20%): Some authors reported on the species' ecological services such as nodulation and its use in intercropping. Nohwar et *al.,* (2019) [92] found that *Rhizobia* species isolated from *S. sesban* root nodules growing in different areas of Mumbai, India, have a capacity to adapt in high salinity (up to 20%) zones and have pH tolerance. They claim that these *Rhizobia* species from *S. sesban* are therefore suitable to be used as biofertilizers in unfavourable environmental conditions for legume cropping and could also help to reduce the use of chemical fertilizers. They propose that they could be tested in agricultural fields to exploit their natural benefits.

Increase the plant cover: *S. sesban* can play an important role, along with other leguminous species, in land restoration and protection and conservation of indigenous species in Chad [47]. In Chad, the local population, particularly pastoralists plant *S. sesban* in the different type of soils in the South region such as the vertisols, fluvisols, subarid soils on sand, tropical ferruginous soils and the arenosol along the banks of Lake Chad [93]. Their objective is to increase the plant cover, to use its wood for construction, and to repel desert encroachment in zones with little vegetation (Ousman B. M., 2024) (unpublished), [7], [22], [47] [90].

Improving fallows: The International Centre for Research in Agroforestry (ICRAF) has had great interested in the role of *S. sesban* in improving fallows especially in the savannah woodland region of southern Africa [94], [5], [4].

Improved fallows involve planting mainly legume tree/shrub species in rotation with cultivated crops. In Eastern Zambia, Phiri et *al.,* (2003) [95] quantified the yield, root zone, soil water balance, and water use efficiency of maize in rotation with 2 years *S. sesban* fallow and of continuous maize with and without fertilizer. The authors found that growing *S sesban* in depleted agricultural fields or on fallow land for 2 or 3 years and then introducing a hybrid maize crop after the fallow period produced encouraging results. S. *sesban* fallow increased grain yield and dry matter production of subsequent maize per unit amount of water used. Average maize grain yields following *S. sesban* fallow and in continuous maize with and without fertilizer were 3, 6, and 1mg/ha with corresponding water use efficiencies of 4.3, 8.8 and 1.7kg/mm/ha, respectively. *S. sesban* fallow increased the soil water storage in the soil profile and drainage below the maximum crop root zone compared with conventionally tilled non-fertilized maize [95]. Many farmers in Eastern Province, Zambia, started using *S. sesban* improved fallows in the late 1990s and early 2000s, but the practice declined for a number of reasons including a reduction in extension support and the introduction of fertilizer subsidies [96].

Detail of use of *S. sesban* for soil improvement in agriculture and in cropping systems are summarized in Table 5.

Table 5. Use of *S. sesban* for soil improvement in agriculture and in cropping systems.

	Detail of use	Part used	References
For soil improvement in agriculture and in cropping systems	*S. sesban* induces in symbiosis the root nodules *Rhizobuim* strains and fixes nitrogen on the soil	Whole tree Germinated seedlings	[78], [28], [79], [80]
	Cultivated in rotation with cotton to enhance nitrogen fertility and improve soil condition	Whole tree	[7], [81]
	Rhizobuim bacteria isolated from *S. sesban* root nodules can tolerate high salinity soil (up to 20%) and high pH, which make them suitable to be used as biofertilizers in unfavourable environmental conditions for legumes cropping	Root nodules	[92]
	S. sesban is planted to increase plant cover in desert areas and area with little vegetation, and to enrich soil fertility for increasing yields of crops in sandy soil and in desert areas	Whole tree	[7], [22], [47], [90], (Ousman B. M., 2024) (unpublished)
	S. sesban improves fallow systems and enhances agricultural productivity by increasing the yields of maize and sorghum	Whole tree	[5], [3], [95], [96].
	The foliar biomass production of *S. sesban* allows the produc of nutrients nitrogen, phosphorus, calcium, magnesium and	Whole tree Bark, Stems	[34], [22]

For soil improvement in agriculture and in cropping systems	potassium when the species is intercropped with *Phaseolus vulgaris* L., *Sorghum bicolor* L., *Zea mays* L., and *Ipomoea batatas* L.		
	S. sesban accessions are used as green manure crops in short fallow and used as sources of organic matter and nitrogen for improvement of poor, nutrient-deficit soils	Seeds accessions Whole tree	[86], [84], [87]
	Intercropping sweet potato with *S. sesban* improves yield of the crop	Whole tree	[88]
	Intercropping of *S. sesban* with rice and annual grasses in semi-arid conditions for managing weeds and optimizing the yield of dry-seeded rice	Whole tree Bark	[22], [89]
	Improved fallows and as herbaceous cover crops	Whole tree	[94], [5], [4], [85]
	Restore eroded soil by fixing N2	Whole tree	[83], [18]
	S. sesban grows in the salt-affected soils and limits the effect of salinity	Whole tree	[82], [91]

Use as feed for livestock and as food for humans

Some studies conducted at the University of Queensland in Australia reported that *S. sesban* was shown to have high nutritive value (28% crude protein) and high dry matter digestibility (86%) [28]. Roothaert and Paterson (1997) [97] found in Kenya that *S. sesban* had the highest dry matter digestibility compared to some common fodder tree species such as *Leucaen, leucocephala* and *Calliandra calothyrsus. S. sesban* also had low acid detergent fiber levels and average crude protein content, which gave it a high nutritive value overall. *S. sesban's* seeds contain 39% protein [98]. One hundred g of dry seeds contained 29–32g of crude protein, 5–6g of crude lipid, 16g of crude fibre, 18–19g of total starch with 7.2–7.4g of digestible starch, 4.85–5.95g of total phenols, 1.97–2.02g of tannins, 5.05–5.14g of condensed tannins, 2.35–2.37g of phytate, and 1.26–1.46g of saponins [98].

Feed for livestock: Numerous studies confirm *S. sesban's* high feed value. Access to adequate livestock feed is the main constraint limiting livestock productivity in Africa [99]. *S. sesban* is widely used as a feed across the continent, as evidenced in the following examples. In Chad, livestock keepers cut, carry, and feed the leaves to ruminants. The pods are cut and fed to dairy sheep, goats, and oxen. The leaves and pods are considered high-protein fodder to increase milk productivity (Ousman B. M., 2024) (unpublished). *S. sesban* is sometimes also cultivated in rotation with sugar cane, or alone as a feed for sheep and goats, which consume the leaves and young stems [7].

Many studies have been conducted in East Africa to assess animal production characteristics such as growth rates, milk production levels, and fertility when cattle, sheep, and goats were fed tree fodder such as *S. sesban* [100]. although its uptake has not been as significant as that of *Calliandra calothyrsus*. However, in Uganda, *S. sesban* is widely grown. In Ethiopia, *S. sesban* is the most important planted fodder tree and is generally grown in home gardens [33]. Smallholders feed it to goats, sheep, and cows. Roothaert and Paterson (1997) [97] also reported on a study in which separate groups of local goats with an average initial age and live weight of 8 months and 8.4kg were allowed to graze daily on the natural ranges for two wet and two dry seasons. They were supplemented at night with sun-dried leaves and small twigs of *S. sesban.* The mean intake was 76g day^{-1} per head and the mean daily live weight gain was 24g day^{-1} per head. Mekoya et *al.,* (2009) [101] conducted a study in the central highlands of Ethiopia on the effect of the supplementation of *S. sesban* on the milk yield of sheep. They concluded that supplementation of *S. sesban* at 30% of the ration (0.98% of their body weight) during lactation improved the milk yield of ewes and the growth rate of lambs compared to supplementation with concentrates. *S. sesban* thus has the potential of increasing milk and meat production of sheep and can serve as a substitute ration to commercial concentrates for resource poor farmers [101]. Studies conducted by Peters (1988) [102] have shown that the leaves of *S. sesban* from Ethiopia are highly nutritious as the crude protein content of the leaves is high (25% to 30% of dry matter) and they contain little tannin and other polyphenols They reported that *S. sesban* is a useful source of protein for ruminant diets, and may prove useful to farmers with livestock and the need for improved fodder [102].

Food for humans: *S. sesban* is not widely consumed by humans, but Bunma & Balslev (2019) [98] reported that there are many uses of *S. sesban* for humans food. Details of use of *S. sesban* as feed for livestock and as food for humans are summarized in Table 6.

Table 6. Use of *S. sesban* as feed for livestock and as food for humans.

	Detail of use	Part used	References
Feed for livestock and food for humans	Potential of improving traditional sheep husbandry by increasing milk and meat production. *S. sesban* has high feed quality	Leaves and young twigs. Whole tree	[101], [33]
	S. sesban had the highest dry matter digestibility		[97]
	S. sesban is used as feed for livestock (cattle, goats, sheep) and thus contributes to improve food security, income and livelihoods. Leaves and pods of *S. sesban* are fed by ruminants and considered as a high-protein fodder increasing milk productivity.	Whole tree Leaves and pods	[102] [28], [100], [33]. (Ousman B. M.,.2024) (unpublished)
	S. sesban is used for humans' food and their nutrition	Seeds	[98]

Other uses of *S. sesban*

As fuelwood: Fuelwood availability is a key problem throughout Africa and particularly in Chad [103]. Robert & Abdel-Hamid [103] reported that some important forest trees (including *S. sesban*) will continue to be used as fuelwood for quite some time to come in most sub-Saharan cities and the sustainability of supply is questionable. Research conducted by the World Agroforestry Centre (2002) [46] found that *S. sesban* is used in many African countries as a source of fuel and is appreciated because it grows fast, burns well and can be coppiced.

In western Kenya, Swinkels et *al.,* (2002) [104] reported that three-quarters of farmers had *S. sesban* in their cropped fields (mainly maize), and that 20 percent planted it. Its main use was as fuelwood but farmers also appreciated its contribution to soil fertility [46]. Adelanwa & Tijani (2016) [105] in Nigeria and Muimba-Kankolongo (2018a) [85] reported that the biomass of *S. sesban* can produce wood within just 3-6 months when grown with *Cajanus cajan* (leguminous).

Shade or shelter, and hedge: *S. sesban* is also used as a shade for humans and their animals, a windbreak, a cover crop, an ornamental plant, as fish poison, and for sticks for construction. It is also used for building huts, making charcoal, and preparing gunpowder [7] [15] [68] (Ousman B. M., 2024) (unpublished). *S. sesban* also grown as a hedge [7].

As fiber for ropes and fishing nets, and as gum: *S. sesban* is used as a fiber for ropes and fishing nets, and the seeds produce gum [46].

Enhancing phytoextraction of heavy metals from soil: Gupta et *al.,* (2011) [106] found that *S. sesban* may enhance the phytoextraction of heavy metals like cadmium (Cd), lead (Pb), and zinc (Zn) from artificially contaminated soil by application of ethylene di-amine tetra-acetic acid (EDTA). They reported that *S. sesban* may enhance chemically by chelate induction, the phytoextraction of the cited heavy metals from the spiked soil through the application of 5mmol EDTA/kg.

Ecological service concerning N nutrition: Dan & Brix (2009) [107] evaluated the growth responses of *S. sesban* to NH_4^+ (about 70mg/l) and NO_3^- in a hydroponic culture. They found that *S. sesban* can grow without an external inorganic N supply by fixing atmospheric N_2 gas via root nodules. They also found that the addition of external concentrations NH_4^+ and NO_3^- alone or mixed at a range of 0, 0.1, 0.2, 0.5, 2, and 5mM stimulated the growth of seedlings of *S. sesban*. Resulting relative growth rates (RGRs) range from 0.19(RGRs)/day and 0.21(RGRs)/day. The authors concluded that these characteristics of *S. sesban* concerning N nutrition make it a very useful plant as N_2-fixing fallow crop in N-deficient areas. Thus, *S. sesban* has a broad ecological amplitude concerning N nutrition, and the wide geographical distribution of this species in subtropical and tropical areas may in part be due to its adaptability to a variety of environmental conditions, including water regime and nutrient availability. *S. sesban* has great use in tropical and subtropical areas not only as a N_2-fixing fallow crop in nutrient deficient areas, but also as a recommended species for use in constructed wetland systems for the treatment of NH_4^+ rich waters.

Treating wastewater in tropical areas: Dan et *al.,* (2011) [108] evaluated the potential of using *S. sesban* as an N_2-fixing plant in constructed wetland systems. *S. sesban* plants grew well in the vertical flow and horizontal flow systems. The parameters measured such as root elongation rate, shoot elongation rate, leaf production rate, and biomass production were generally high in the two systems. The biomass production for the experimental periods was 20.2 and 17.2 kg/m_2/year for the vertical flow and horizontal flow systems, respectively. Nitrogen content in *S. sesban* biomass was relatively high in general. They concluded that *S. sesban* can be used to treat high-strength wastewater in tropical areas while the species grows well and produces a large amount of nitrogen containing biomass which is used as fodder and for soil amendment [108].

Gas production and rumen degradation characteristics: *S. sesban* leaves are investigated *in vitro* and in *sacco* in rumen fistulated cows fed on a diet of grass hay ad libitum supplemented with cotton seed cake [72]. The results showed that *S. sesban*' leaves are used for gas production (methane, carbon dioxide) and rumen degradation characteristics, and the growing of *S. sesban* leaves (in a heavy clay vertisols with near neutral to alkaline pH (6-8)). offered advantages over herbaceous species in terms of superior persistence, higher dry matter (DM) yields, better resistance to mismanagement and a capacity to retain high-quality foliage livestock depend on grazing unimproved native under stress conditions. It provides also fertilizer in the pastures and crop residues, and can play a role as protein supplements to poor quality forages [72]. Details of other uses of *S. sesban* discussed in this section are summarized in Table 7.

Table 7. Other uses of *S. sesban.*

	Detail of use	Part used	References
Other uses	*S. sesban* biomass is used as firewood for cooking and heating.	Whole tree	[46], [103] [105], [85]
	S. sesban is used as shade. windbreaks, cover crops, ornamental plant, as fish poison and sticks for construction and as hedge	Whole tree	[7], [15] [68] (Ousman B. M., 2024) (unpublished)
	As fiber for ropes and fishing nets, and the seeds produce a gum	Stem and thick branches, Bark	[46].
	S. sesban may enhance chemically the phytoextraction of heavy metals (cadmium, lead, and zinc) from the soil, when 5mmol EDTA/kg is applied.	Whole tree	[106], [107]
	S. sesban can tolerate relatively high concentrations of ammoniac ion NH4+ in a hydroponic culture	Whole tree	[107]
	S. sesban, as an N2-fixing shrub, is used for treatment of polluted water	Whole tree	[108]
	S. sesban leaves are investigated *in vitro* and in *sacco* in rumen fistulated cows fed to produce gas and rumen degradation characteristics, higher dry matter (DM) yields, better resistance to mismanagement and a capacity to retain high-quality foliage livestock depend on grazing unimproved native under stress conditions.	Leaves	[72]

Conclusion

S. sesban is a leguminous tree native to Chad used to increase crop yields and vegetation in some desert areas. The local population and particularly pastoralists plant it in arid zones to increase the plant cover, to obtain shade for humans and their animals, and to use its wood for construction. The local population also uses *S. sesban* to enrich soil fertility for increasing yields of crops such as rice, maize, and sorghum. The species is also used also as a medicinal plant to treat breast cancer, wounds and oedema. However, some important problems exist which threaten *S. sesban* and other leguminous trees in Chad. Robert & Abdel-Hamid (2005) [103] pointed out that around cities such as Ndjamena; the high demand for fuelwood threatens the sustainability of supply. They also explained that this demand for fuelwood does not need to be a problem; if supplies are made available then woodfuel can also be an engine of economic growth, particularly in rural areas.

Land degradation, decline of soil fertility and carbon stocks, and reduced availability of fuelwood and livestock feed are key problems in Chad as well as throughout Africa. Nwilo et *al.,* (2020) [109] noted that vegetation in northern Nigeria including the region of Lake Chad declined by 49.3% between 1984 and 2016. The causes included agricultural activities such as extensive grazing and annual cropping, deforestation, and variations in climate. Excessive exploitation poses risks to the conservation of the whole flora in these and other tropical and subtropical regions [110], [111]. Moreover, effective strategies for biodiversity conservation should focus on regions with rare and endangered species, on locally abundant species that are functionally vital in maintaining the plant community, and on regions with considerable heterogeneity of vegetation [111]. Rukangira (2001) [110] noted that policy makers, other stakeholders, and citizens need to support conservation and help increase awareness of the problem. The collection of plant material and documentation, botanical identification, and preparation of herbarium vouchers are tasks that cannot be automated and thus require specialists who are becoming increasingly rare [112], [113]. As reported by Mosier et *al.,* (2021) [114] restoring soil fertility on degraded lands to meet food, fuel, and climate security needs perennial cropping systems using perennial vegetation and thus can simultaneously provide additional ecosystem services. These alternative combinations of ecosystem services are climate change mitigation (bioenergy cropping systems), animal protein production (intensive rotational grazing), and biodiversity restoration (conservation plantings).

Finally, this review paper demonstrates that *S. sesban* has considerable potential for addressing problems such land degradation, decline of soil fertility and carbon stocks and reduced availability of fuelwood and livestock feed as well as for improving human and livestock health and treating diseases. Various phytochemical constituents with essential metabolites and drugs can be extracted from different parts of *S. sesban* including the leaves, bark, stem, flower, roots, and seedpods. *S. sesban* also has important uses in particular niches, such as on saline soils, constructed wetlands, and for phytoextraction of metals. This paper contributes to the knowledge base on *S. sesban* and will hopefully help in its protection, use, and value for future generations. Although the plant grows naturally in and around N'Djamena, it has become rare and needs to be replanted in order to avoid its complete disappearance in the future.

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References

[1] F. Z. Lahdachi, L. Nassiri, J. Ibijbijen, and and F. Mokhtari, "Aperçu sur les Acacias spontanés et introduits au Maroc.," *Eur. Sci. J.*, vol. 11, no. 23, pp. 88–102, 2015, [Online]. Available: https://www.researchgate.net/publication/282217944_APERCU_SUR_LES_ACACIAS_SPONTANES_ET_INTRODUITS_AU_MAROC.

[2] P. S. Bindraban, M. van der Velde, L. Ye, M. van den Berg, S. Materechera, D .I. Kiba, L. Tamene, K. V. Ragnarsdottir, R. Jongschaap, M. Hoogmoed, W. Hoogmoed, C. van Beek and G. van Lynden, "Assessing the impact of soil degradation on food production," *Curr. Opin. Environ. Sustain.*, vol. 4, no. 5, pp. 478–488, 2012, doi: 10.1016/j.cosust.2012.09.015.

[3] G. W. Sileshi, P. L. Mafongoya, F. K. Akinnifesi, E. Phiri, P. Chirwa, T. Beedy, W. Makumba, G. Nyamadzawo, J. Njoloma, M. Wuta, P. Nyamugafata and O. Jiri, "Agroforestry: Fertilizer Trees," *Encycl. Agric. Food Syst.*, vol. 1, pp. 222–234, 2014, doi: 10.1016/B978-0-444-52512-3.00022-X.

[4] F. R. Kwesiga, S. Franzel, F. Place, D. Phiri, and C. P. Simwanza, "Sesbania sesban improved fallows in eastern Zambia: Their inception, development and farmer enthusiasm," *Agrofor. Syst.*, vol. 47, no. 1–3, pp. 49–66, 1999, doi: 10.1023/a:1006256323647.

[5] J. N. Ndungu and D. Boland, "Sesbania seed collections in Southern Africa Developing a model for collaboration between a CGIAR Centre and NARS," *Agrofor. Syst.*, vol. 27, pp. 129–143, 1994, doi: 10.1007/BF00705470.

[6] C. Orwa, A. Mutua, R. Kindt, R. Jamnadass, and S Anthony, "Agroforestree Database:a tree reference and selection guide version 4.0," 2009. [Online]. Available: http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp.

[7] M. G. Curasson, *Etudes sur les pâturages tropicaux et sub-tropicaux: Legumineuses*

fourragères. (1956). Revue d'élevage et de médecine vétérinaire des pays tropicaux, p. 49-84, 1956. https://www.researchgate.net/publication/318309602_Etudes_sur_les_paturages_tropicaux_et_subtropicaux_plantes_appartenant_a_des_familles_autres_que_les_graminees_et_les, 1956.

[8] Y. Bashan, Bernardo G Salazar, M. Moreno, Blanca R Lopez, and Robert G Linderman, "Restoration of eroded soil in the Sonoran Desert with native leguminous trees using plant growth-promoting microorganisms and limited amounts of compost and water," *J. Environ. Manage.*, vol. 102, pp. 26–36, 2012, doi: 10.1016/j.jenvman.2011.12.032.

[9] M. Bradbury, "The effect of water stress on growth and dry matter distribution in juvenile Sesbania sesban and Acacia nilotica," *J. Arid Environ.*, vol. 18, no. 3, pp. 325–333, 1990, doi: 10.1016/s0140-1963(18)30842-5.

[10] J. H. Heering, "Botanical and agronomic evaluation of a collection of Sesbania sesban and related perennial species," Thesis, p. 124. Wageningen Agricultural University, Wageningen, The Netherlands., 1995.

[11] J. C. Dagar and V. P. Tewari, *Agroforestry: Anecdotal to Modern Science.* New Delhi 132001 - Himachal Pradesh, India: Springer Nature Singapore Pte Ltd. p. 869., 2017.

[12] R. P. K. Nair, *An Introduction to Agroforestry.* Dordrecht, The Netherlands.: p. 489. Kluwer Academic Publishers, Dordrecht, The Netherlands., 1993.

[13] A. Gaston and G. Fotuis, *Lexique de noms vernaculaires de plantes du Tchad*. Fort-Lamy NDjamena (Tchad): p. 355. Laboratoire de Farcha, Fort-Lamy NDjamena,Tchad., 1971.

[14] J. César and C. Chatelain, *Flore illustrée du Tchad*. Geneve and Ndjamena: Conservatoire et Jardin botaniques de la Ville de Genève en co-édition avec l'Université de N'Djaména et la Coopération Suisse au Tchad, p. 387., 2019.

[15] J. B. Gillett, "Sesbania in Africa (Excluding Madagascar) and Southern Arabia," *Plants People Possibilities Springer behalf R. Bot. Gard. Kew*, vol. 17, no. 1, pp. 91–159, 1963, [Online]. Available: http://www.jstor.org/stable/4118710.

[16] C. Auguste, "Etudes sur la flore de l'Afrique centrale française (Bassins de l'Oubangui et du Chari) Tome I. Enumération des plantes récoltées.," *Université de Cornell and Paris, A. Challamel, Mission Chari-Lac Tchad.*, 1913. http://www.ipni.org/ipni/idAuthorSearch.do;jsessionid=CABB88F11DFEAC53116E0A7296EFB841?id=1584- 1&back_page%0AChevalier (accessed Jan. 21, 2019).

[17] J. G. Baker, "The Leguminosae of Tropical Africa (1926).): Base de données des plantes d'Afrique: Sesbania tchadica A. Chev.," *Conservatoire et Jardin botaniques & South African National Biodiversity Institute.*, 1926. http://www.ville-

ge.ch/musinfo/bd/cjb/africa/details.php?langue=fr&id=127976 (accessed Jun. 27, 2020).

[18] T. Degefu, Endalkachew Wolde-meskel, and Åsa Frostegård, "Multilocus sequence analyses reveal several unnamed Mesorhizobium genospecies nodulating Acacia species and Sesbania sesban trees in Southern regions of Ethiopia," *Syst. Appl. Microbiol.*, vol. 34, no. 3, pp. 216–226, 2011, doi: 10.1016/j.syapm.2010.09.006.

[19] S. Taugourdeau, P. Daget, C. Chatelain, D. Mathieu, X. Juanes, J. Huguenin and A. Ickowicz, "FLOTROP, a massive contribution to plant diversity data for open ecosystems in northern tropical Africa," *Sci. Data*, vol. 6, no. 1, pp. 4–11, 2019, doi: 10.1038/s41597-019-0120-8.

[20] IPNI International Plant Names Index, "Sesbania sesban (L.) Merr.," *International Plant Names Index IPNI*, 2023. https://www.ipni.org/n/1118802-2 (accessed Dec. 04, 2023).

[21] R. Jamnadass, Jean Hanson, Jane Poole, Olivier Hanotte, Tony J Simons, and Ian K Dawson, "High differentiation among populations of the woody legume Sesbania sesban in sub-Saharan Africa : Implications for conservation and cultivation during germplasm introduction into agroforestry systems," *For. Ecol. Manage.*, vol. 210, pp. 225–238, 2005, doi: 10.1016/j.foreco.2005.02.033.

[22] M. Abbas, M. Monib, A. Rammah, M. Fayez, and N. Hegazi, "Intercropping of sesbania (Sesbania sesban) and leucaena (Leucaena leucocephala) with five annual grasses under semi-arid conditions as affected by inoculation with specific rhizobia and associative diazotrophs," *Agronomie*, vol. 21, no. 6–7, pp. 517–525, 2001, doi: 10.1051/agro:2001141.

[23] Royal Botanic Gardens Kew, "Sesbania sesban (L.) Merr.," *Plants Of the World Online*, 2021. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:51 8533-1 (accessed Dec. 05, 2023).

[24] R. Kindt, A. Abiyu, P. Borchardt, I. Dawson, S. Demissew, L. Graudal, R. Jamnadass, J-pb. Lillesø, S. Moestrup, F. Pedercini, J. Wieringa and T. Wubalem, "A climate change atlas for Africa of tree species prioritized for forest landscape restoration in Ethiopia.," *Atlas World Agroforestry, Climate Change Atlas*, 2021. https://atlas.worldagroforestry.org/ (accessed Dec. 04, 2023).

[25] Dufour-Dror J. M., "Israel's Least Wanted Alien Ornamental Plant Species [ed. by Dufour-Dror, J. M.]., Israel: Information and Internet Division," *Israel Ministry of Environmental Protection*, 2013. http://www.moag.gov.il/en/Ministrys Units/Plant Protection and Inspection Services/Publications/2013/Documents/zanim_polshim_en.pdf (accessed Dec. 08, 2023).

[26] Cabi digital library, "Sesbania sesban (sesban)," *Cabi Compendium*, 2015. https://doi.org/10.1079/cabicompendium.49466 (accessed Dec. 08, 2023).

[27] GBIF Global Biodiversity Information Facility, "Sesbania sesban (L) Merr. Chad. Naturalis

Biodiversity Center.," *FLOTROP, a massive contribution to plant diversity data for open ecosystems in Tropical Africa. Published by CIRAD SELMET*, 2020. https://www.gbif.org/occurrence/map?country=TD&has_coordinate=true&has_geospatial_issue=false&taxon_key=2970648 (accessed Apr. 21, 2021).

[28] S. Daniel, "Sesbania sesban, var. 'Mount Cotton' Available," Hawaii, 2001. [Online]. Available: https://api.echocommunity.org/pdf/en/97dc5dd1-da8e-4b40-94cd-f873343f9470/sesbania-sesban-va-available.pdf.

[29] S. T. Partey, R. B. Zougmor, M. Ouédraogo, and N. V. Thevathasan, "Why Promote Improved Fallows as a Climate-Smart Agroforestry Technology in Sub-Saharan Africa ?," *Sustainability*, vol. 9, pp. 1–12, 2017, doi: 10.3390/su9111887.

[30] G. Ouma and F. Gottwald, *Agrarian Science for Sustainable Resource Management in Sub-Saharan Africa*. Berlin: Peter Lang. p. 129. Google book., 2009.

[31] S. R. Shaikh, P. T. Vijay, and Md. Rageeb Md. U., "Anti-Inflammatory activity of Sesbania sesban (L) Merr.," *Int. Res. J. Pharm.*, vol. 3, no. 1, pp. 176–180, 2012, [Online]. Available: https://pdfs.semanticscholar.org/1822/c44801e7e849685ddf3ce9310e702cc91d5d.pdf.

[32] V. Heuzé, G. Tran, and D. Bastianelli, "Sesban (Sesbania Sesban).," *Feedipedia, a programme by INRA, CIRAD, AFZ and FAO.*, 2016. https://www.feedipedia.org/node/253 (accessed Sep. 30, 2020).

[33] S. Franzel, S. Carsan, B. Lukuyu, J. Sinja, and C. Wambugu, "Fodder trees for improving livestock productivity and smallholder livelihoods in Africa," *Curr. Opin. Environ. Sustain.*, vol. 6, no. 1, pp. 98–103, 2014, doi: 10.1016/j.cosust.2013.11.008.

[34] V. Balaisubramanian and L. Sekayange, "Effets de la culture en couloirs sur les propriétés du sol et les performances des arbustes et des cultures vivrières dans un environnement semi-aride au Rwanda," *Int. Rice Res. Inst.*, pp. 180–190, 1992, [Online]. Available: https://www.researchgate.net/publication/32976933.

[35] T. P. Mall and P. G. Kisan, "Virus diseases of dhaincha Sesbania aculeata Pers.," *J. liv-World India*, vol. 10, no. 2, pp. 16–19, 2003, [Online]. Available: https://www.researchgate.net/publication/327466758%0AVirus.

[36] G. Sileshi, J. A. Maghembe, M. R. Rao, C. K. P .O. Ogol, and S. Sithanantham, "Insects feeding on Sesbania species in natural stands and agroforestry systems in southern Malawi," *Agrofor. Syst.*, vol. 49, no. 1, pp. 41–52, 2000, doi: 10.1023/A:1006378713271.

[37] R. P. Mani, P. Awanish, G. Shambaditya, Tripathi Poonam, V. Kumudhavalli, and Singh Ajay Pratap, "Phytochemical Screening and In-vitro Evaluation of Antioxidant Activity and Antimicrobial Activity of the Leaves of Sesbania sesban (L) Merr.," *Free Radicals Antioxidants*, vol. 1, no. 3, pp. 66–69, 2011, doi: 10.5530/ax.2011.3.9.

[38] M. Kathiresh, P. Suganya Devi, and M. Saravanakumar, “Bioactive compounds in Sesbania sesban flower and its antioxidant and antimicrobial activity,” *J. Pharm. Res.*, vol. 5, no. 1, pp. 390–293, 2012, [Online]. Available: https://jprsolutions.info/article_detail.php?article_id=1430.

[39] T. Mythili and R. Ravindhran, “Phytochemical screening and antimicrobial activity of Sesbania sesban (L.) Merr,” *Asian J. Pharm. Clin. Res.*, vol. 5, no. 4, pp. 179–182, 2012.

[40] A. U. Tatiya, Payal R. Dande, Rakesh E. Mutha, and Sanjay J. Surana, “Effect of saponins from of Sesbania sesban L. (Merr) on acute chronic inflammation in experimental induced animals,” *J. Bio-Sciences*, vol. 13, no. 3, pp. 123–130, 2013, doi: 10.3923/jbs.2013.123.130.

[41] D. Valke, “Sesbania sesban: Tree,” *Flowers of India https://www.flowersofindia.net/catalog/slides/Prickly Sesban.html*, 2007. https://creativecommons.org/licenses/by-sa/2.0 (accessed Dec. 13, 2023).

[42] L. Shun-ching, “The Study on the effect of light to the development and growth of Sesbania Sesban (Merr.),” *Taiwania Journal. Natl. Taiwan Univ. Biodivers. Assoc. Taiwan*, vol. 7, no. 1, pp. 9–15, 1960, doi: 10.6165/tai.1960.7.9.

[43] Forest Starr and Kim Starr, “Sesbania sesban (Sesban),” *Pono Grown Farm Center Olinda, Maui, Hawaii. USA. https://commons.wikimedia.org/w/index.php?search=Sesbania+sesban&title=Special:MediaSearch&go=Go&type=image*, 2015. https://creativecommons.org/licenses/by/3.0/us/deed.en (accessed Dec. 14, 2023).

[44] R. Bijmoer, M. Scherrenberg, and J. Creuwels, “Naturalis Biodiversity Center (NL) - Botany . Naturalis Biodiversity Center . Occurrence dataset https://doi.org/10.15468/ib5ypt. Accessed via gbif on 2023-12-15 https://www.gbif.org/occurrence/2515653619 and https://www.gbif.org/occurrence/1840360064,” *GBIF—Global Biodiversity Information Facility*, 2023. https://www.gbif.org/occurrence/2515653619 (accessed Dec. 15, 2023).

[45] M. Moyo, A. O. Aremu, J. Van Staden, “Medicinal plants: An invaluable, dwindling resource in sub-Saharan Africa,” *J. Ethnopharmacol.*, vol. 174, pp. 595–606, 2015, doi: 10.1016/j.jep.2015.04.034.

[46] World Agroforestry Centre, “Sesbania sesban.,” p. 2., 2002. [Online]. Available: http://www.worldagroforestry.org/treedb/AFTPDFS/Sesbania_sesban.PDF.

[47] FAO Food and Agriculture Organisation, “Synthèse des études thématiques sur la foresterie urbaine et périurbaine de N’Djaména, Republique du Tchad. Document de travail sur la foresterie urbaine et périurbaine n°7.,” Rome and NDjamena, 2012. [Online]. Available: http://www.fao.org/3/i2850fwp7/i2850fwp7.pdf.

[48] S. M. Abdelgawad, M. H. Hetta, M. A. Ibrahim, G. A. Fawzy, H. I. El-Askary, and S. A. Ross, “Holistic Overview of the Phytoconstituents and Pharmacological Activities of Holistic Overview of the Phytoconstituents and Pharmacological Activities of Egyptian Riverhemp [Sesbania sesban (L .) Merr .]: A Review,” *Nat. Prod. Commun.*, vol. 18, no. 3, pp. 1–11, 2023, doi: 10.1177/1934578X231160882.

[49] M. N. Walekhwa, T. K. Ogeto, M. K. Murithi, and Z. L. Malago, “Pharmacological effects of Sesbania sesban: a systematic review,” *Int. J. Res. Med. Sci.*, vol. 8, no. 3, p. 1185, 2020, doi: 10.18203/2320-6012.ijrms20200803.

[50] Arif Ahmed, Md. S. Islam Howlader, S. Kanti Dey, A. Hira and Md. H. Hossain, “Phytochemical screening, antimicrobial and cytotoxic activity of different fractions of Sesbania sesban bark,” *Int. J. Basic Med. Sci. Pharm.*, vol. 5, no. 4, p. 206, 2013, doi: 10.4103/1947-489x.210546.

[51] A. M. Ibrahim, “Anthelmintic Activity of some Sudanese Medicinal Plants,” *Phyther. Res.*, vol. 6, pp. 155–157, 1992, doi: 10.1002/ptr.2650060312.

[52] R. P. Limsay, C. R. Jangde, A. Jahan, and Uma. P. Swati, “In vitro anthelmintic activity of hydroethanolic and aqueous Sesbania sesban, pers. leaf extract against Moneizia expansa and Paramphistomes,” *Int. J. Pharm. Pharm. Sci.*, vol. 6, no. 2, pp. 504–505, 2014.

[53] Vijaya, A. K. Yadav, and S. Gogoi, “In vitro and in vivo anthelmintic efficacy of two pentacyclic triterpenoids , ursolic acid and betulinic acid against mice pinworm , Syphacia obvelata,” *J. Parasit. Dis.*, vol. 42, no. 1, pp. 144–149, 2018, doi: 10.1007/s12639-017-0960-0.

[54] F. O. Santos, A. P. M. Cerqueira, A. Branco, M. J. M. Batatinha, and M. B. Botura, “Anthelmintic activity of plants against gastrointestinal nematodes of goats : a review,” *Parasitology*, vol. 146, no. 10, pp. 1–14, 2019, doi: 10.1017/ S0031182019000672.

[55] E. G. Kamel, M. A. El-Emam, S. S.M. Mahmoud, F. M. Fouda, and F. E. Bayaumy, “Parasitological and biochemical parameters in Schistosoma mansoni-infected mice treated with methanol extract from the plants Chenopodium ambrosioides, Conyza dioscorides and Sesbania sesban,” *Parasitol. Int.*, vol. 60, no. 4, pp. 388–392, 2011, doi: 10.1016/j.parint.2011.06.016.

[56] A. A. Elegami, Aisha Z. Almagboul, Mohamed Elfatih A. Omer, and Mahgoub S. El Tohami, “Sudanese plants used in folkloric medicine: Screening for antibacterial activity. Part X,” *Fitoterapia*, vol. 72, no. 7, pp. 810–817, 2001, doi: 10.1016/S0367-326X(01)00310-0.

[57] R. B. Pandhare, B. Sangameswaran, P. B. Mohite, and S. G. Khanage, “Antidiabetic activity of aqueous leaves extract of Sesbania sesban (L) Merr. in streptozotocin induced diabetic rats,” *Avicenna J. Med. Biotechnol.*, vol. 3, no. 1, pp. 37–43, 2011, doi:

10.1093/neuonc/nos096.

[58] Manjusha, N. Aggarwal, Nitesh and P. Gupta, “Effect of petroleum ether extract of Sesbania sesban (Merr.) roots in streptozotocin (STZ) induced diabetes in mice,” *Asian Pac. J. Trop. Biomed.*, vol. 2, no. 3 SUPPL., pp. S1254–S1260, 2012, doi: 10.1016/S2221-1691(12)60395-5.

[59] S. A. Nirmal, J. H. Bairagi, A. N. Patii, S. C. Pal, C. D. Upasani, and S. C. Mandal, “Antinociceptive activity of Sesbania sesban (Linn) wood extracts, a preliminary study,” *Indian J. Exp. Biol.*, vol. 50, no. 1, pp. 61–64, 2012.

[60] B. Sheikholeslami, B. Jamali, and M. Rouini, *Tramadol, Usage, Misuse, and Addiction Processes*, vol. 3. Elsevier Inc., 2016.

[61] P. S. Shiv, “Fertility Control of Female through Sesbani Sesbian Seeds,” *J. Res. Educ. Indian Med.*, vol. 9, no. 4, pp. 27–32, 1990, [Online]. Available: https://pdfs.semanticscholar.org/.../1ce2e6e2570d7d0d42eace6065...%0A.

[62] D. Nilanjana, P. Chandran, and C. Smritinath, “Potent spermicidal effect of oleanolic acid 3-beta-d-glucuronide, an active principle isolated from the plant Sesbania sesban Merrill,” *Contraception*, vol. 83, no. 2, pp. 167–175, 2011, doi: 10.1016/j.contraception.2010.05.009.

[63] N. N. Naik, H. L. Tare, A .K. Sherikar, S. R. Deore, and G. Y. Dama, “Central Nervous System Stimulant Effect of Extracts Obtained From the Barks of Sesbania Sesban,” *Int. J. institutional Pharm. life Sci.*, vol. 1, no. 1, pp. 77–92, 2011, [Online]. Available: http://www.ijipls.com/uploaded/journal_files/110715110700.pdf.

[64] W. S. Hasheesh, R. T. Mohamed, and S. Abd El-Monem, “Biological and physiological parameters of Bulinus truncatus snails exposed to methanol extract of the plant Sesbania sesban plant,” *Adv. Biol. Chem.*, vol. 01, no. 03, pp. 65–73, 2011, doi: 10.4236/abc.2011.13009.

[65] M. B. Mahmoud, W. L. Ibrahim, B. M. Abou-El-Nour, M. A. El-Emam, and Al. A. Youssef, “Biological and biochemical parameters of Biomphalaria alexandrina snails exposed to the plants Datura stramonium and Sesbania sesban as water suspensions of their dry powder,” *Pestic. Biochem. Physiol.*, vol. 99, no. 1, pp. 96–104, 2011, doi: 10.1016/j.pestbp.2010.11.005.

[66] T. M. Kutchan, “Ecological Arsenal and Developmental Dispatcher. The Paradigm of Secondary Metabolism PLANTS PRODUCE A LARGE NUMBER OF CHEMICALS OF DIVERSE STRUCTURE AND CLASS,” *Plant Physiol.*, vol. 125, no. January, pp. 58–60, 2001, [Online]. Available: www.plantphysiol.org.

[67] A. K. Patra, P. K. Chhonkar, and M. A. Khan, “Effect of green manure Sesbania sesban and nitrification inhibitor encapsulated calcium carbide (ECC) on soil mineral-N , enzyme

activity and nitrifying organisms in a rice – wheat cropping system," *Eur. J. Soil Biol.*, vol. 42, pp. 173–180, 2006, doi: 10.1016/j.ejsobi.2005.12.007.

[68] S. Samajdar and A. Kr. Ghosh, "Pharmacological effects of Sesbania sesban Linn : An overview," *PharmaTutor*, vol. 5, no. 7, pp. 16–21, 2017, [Online]. Available: https://www.pharmatutor.org/articles/magazines/articles/july-2017/pharmacological-effects-of-sesbaniasesbanlinn-an-overview.

[69] C. P. Khare, *Indian Medicinal Plants:An Illustrated Dictionary.* New Delhi 132001 - Himachal Pradesh, India: p. 900. Springer-Verlag New York., 2007.

[70] S. Goswami, K. Mishra, R. P. Singh, and P. S. PradeepSingh, "Sesbania sesban, A Plant with Diverse Therapeutic Benefits : An Overview," *J. Pharm. Res. Educ.*, vol. 1, no. 1, pp. 111–112, 2016, [Online]. Available: https://www.researchgate.net/publication/307601150%0ASesbania.

[71] R. J. Kaitho, "Nutritive value of browses as protein supplement to poor quality roughages," Thesis, p. 196. Landbouw Universiteit Wageningen. - With réf. - With summary in Dutch. ISBN90-5485-735-8, 1997.

[72] D. E. K. A. Siaw, P. O. Osuji, and L. V. Nsahlai, "Evaluation of multipurpose tree germplasm the use of gas production and rumen degradation characteristics," *J. Agric. Sci.*, vol. 120, no. 3, pp. 319–330, 1993, doi: 10.1017/S0021859600076486.

[73] Md. Harun-or-Rashid, R. Tanzin, K. C. Ghosh, R. Jahan, Mst. A. Khatun and M. Rahmatullah, "An ethnoveterinary survey of medicinal plants used to treat cattle diseases in Birishiri area, Netrakona district, Bangladesh," *Adv. Nat. Appl. Sci.*, vol. 4, no. 1, pp. 10–13, 2010, [Online]. Available: https://www.researchgate.net/publication/289176508_An_ethnoveterinary_survey_of_medicinal_plants_used_to_treat_cattle_diseases_in_Birishiri_area_Netrakona_district_Bangladesh.

[74] M. Rahmatullah *et al.*, "An Ethnoveterinary Survey of Medicinal Plants Used by Folk Medicinal Practitioners to Treat Cattle Diseases in Randomly Selected Areas of Bagerhat District, Bangladesh," *Am. J. Sustain. Agric.*, vol. 4, no. 3, pp. 386–396, 2010, [Online]. Available: https://www.academia.edu/5776667/An_Ethnoveterinary_Survey_of_Medicinal_Plan_ts_Used_by_Folk_Medicinal_Practitioners_to_Treat_Cattle_Diseases_in_Randomly_Select_ed_Areas_of_Bagerhat_District_Bangladesh.

[75] T. Sori, M. Bekana, G. Adugna, and E. Kelbessa, "Medicinal Plants in the Ethnoveterinary Practices of Borana Pastoralists, Southern Ethiopia," *Intern J Appl Res Vet Med*, vol. 2, no. 3, pp. 220–225, 2004.

[76] K. C. Chinsembu, “Plants as antimalarial agents in Sub-Saharan Africa,” *Acta Trop.*, vol. 152, pp. 32–48, 2015, doi: 10.1016/j.actatropica.2015.08.009.

[77] P. Rasoanaivo, A. Petitjean, S. Ratsimamanga-Urverg, and A. Rakoto-Ratsimamanga, “Medicinal plants used to treat malaria in Madagascar,” *J. Ethnopharmacol.*, vol. 37, pp. 117–127, 1992, doi: 10.1016/0378-8741(92)90070-8.

[78] A. T. Sobere, “Contribution à l’étude de la nodulation de tige par rhizobium chez une légumineuse aquatique, Sesbania pubescens.,” p. 98. Maitrise en Sciences Agronomique. Faculté des Sciences et Techniques, département de Biologie Végétale, Bibliothèque Numérique, Université Cheikh Anta Diop Dakar, Sénégal., 1991.

[79] A. Bala, P. Murphy, and E. Giller Ken, “Occurrence and genetic diversity of rhizobia nodulating Sesbania sesban in African soils,” *Soil Biol. Biochem.*, vol. 34, no. 11, pp. 1759–1768, 2002, doi: 10.1016/S0038-0717(02)00163-3.

[80] R. S. Sharma, A. Mohammed, V. Mishra, and C. R. Babu, “Diversity in a promiscuous group of rhizobia from three Sesbania spp. colonizing ecologically distinct habitats of the semi-arid Delhi region,” *Res. Microbiol.*, vol. 156, no. 1, pp. 57–67, 2005, doi: 10.1016/j.resmic.2004.08.009.

[81] I. J. Rochester, M. B. Peoples, N. R. Hulugalle, R. R. Gault, and G. A. Constable, “Using legumes to enhance nitrogen fertility and improve soil condition in cotton cropping systems,” *F. Crop. Res.*, vol. 70, no. 1, pp. 27–41, 2001, doi: 10.1016/S0378-4290(00)00151-9.

[82] N. Bakhoum, D. Fall, F. Fall, F. Diouf, A. M. Hirsch, D. Balachandar and D. Diouf, “Senegalia senegal (synonym : Acacia senegal), its importance to sub-Saharan Africa , and its relationship with a wide range of symbiotic soil microorganisms,” *South African J. Bot.*, vol. 119, pp. 362–368, 2018, doi: 10.1016/j.sajb.2018.10.007.

[83] Z. Nigussie and A. Getachew, “Sesbania sesban (L.) Merrill: Potential uses of an underutilized multipurpose tree in Ethiopia,” *African J. Plant Sci.*, vol. 7, no. 10, pp. 468–475, 2013, doi: 10.5897/AJPS2012.0716.

[84] S. Mengistu, D. Keftasa, and A. Yami, “Productivity of four sesbania species on two soil types in Ethiopia,” *Agrofor. Syst.*, vol. 54, no. 3, pp. 235–244, 2002, doi: 10.1023/A:1016072504983.

[85] A. Muimba-Kankolongo, *Food Crop Production by Smallholder Farmers in Southern Africa: Challenges and Opportunities for Improvement*. Academic Press. p. 368, 2018a., 2018.

[86] S. C. Chanda, A. K. M. Azad-ud-doula Prodhan, and A. K. M. Golam Sarwar, “Screening of Sesbania accessions based on early biomass yield,” *J. Bangladesh Agric. Univ.*, vol. 15, no. 2, pp. 188–192, 2017, doi: 10.3329/jbau.v15i2.xxxxx.

[87] R. J. K. Myers, C. A. Palm, E. Cuevas, I. U. N. Gunatilleke, and M. Brossard, “The synchronisation of nutrient mineralisation and plant nutrient demand,” *Biol. Manag. Trop. soil Fertil.*, no. January, pp. 81–116, 1994.

[88] A. Muimba-Kankolongo, “Root and Tuber Crops,” in *Food Crop Production by Smallholder Farmers in Southern Africa*, Academic Press. Chap. 9. p. 123-172, 2018b, 2018.

[89] S. Singh, J. K. Ladha, R. K. Gupta, L. Bhushan, A. N. Rao, B. Sivaprasad and P. P. Singh, “Evaluation of mulching, intercropping with Sesbania and herbicide use for weed management in dry-seeded rice (Oryza sativa L.),” *Crop Prot.*, vol. 26, no. 4, pp. 518–524, 2007, doi: 10.1016/j.cropro.2006.04.024.

[90] INRA, “Maroc : Premier Forum international sur l ’agriculture biosaline à Laâyoune. Des exemples réussis de cultures résilientes en milieu salin,” *Institut National de la Recherche Agronomique INRA, Maroc.*, 2019. https://www.inra.org.ma/fr/content/05052019-des-exemples-réussis-de-cultures- résilientes-en-milieu-salin-à-foum-el-oued. http://agripeche.com/4239-maroc- premier-forum-international-sur-lagriculture-biosaline-a-laayoune.html (accessed Sep. 09, 2019).

[91] N. Bala, P. K. Sharma, and K. Lakshminarayana, “Nodulation and nitrogen fixation by salinity-tolerant rhizobia in symbiosis with tree legumes,” *Agric. Ecosyst. Environ.*, vol. 33, no. 1, pp. 33–46, 1990, doi: 10.1016/0167-8809(90)90142-Z.

[92] N. Nohwar, R. V. Khandare, and N. S. Desai, “Isolation and characterization of salinity tolerant nitrogen fixing bacteria from Sesbania sesban (L) root nodules,” *Biocatal. Agric. Biotechnol.*, vol. 21, p. 101325, 2019, doi: 10.1016/j.bcab.2019.101325.

[93] O. Dewitte, A. Jones, O. Spaargaren, H. Breuning-Madsen, M. Brossard, A. Dampha, J. Deckers, T. Gallali, S. Hallett, R. Jones, M. Kilasara, P. Le Roux, E. Michéli, L. Montanarella, L. Thiombiano, E. Van Ranst, M. Yemefack and R. Zougmore, “Harmonisation of the soil map of africa at the continental scale,” *Geoderma*, vol. 211–212, pp. 138–153, 2013, doi: 10.1016/j.geoderma.2013.07.007.

[94] ICRAF 1992. Annual Report 1991 and International Centre for Research in Agroforestry ICRAF. Nairobi., “In: Ndungu J. N. and Boland D. J. (1994). Sesbania seed collections in Southern Africa. Developing a model for collaboration between a CGIAR Centre and NARS. Agrolbrestry Systems 27: 129-143.,” 1992.

[95] E. Phiri, H. Verplancke, F. Kwesiga, and P. Mafongoya, “Water balance and maize yield following improved sesbania fallow in eastern Zambia,” *Agrofor. Syst.*, vol. 59, pp. 197–205, 2003, doi: 10.1023/B.

[96] M. Jacobson and C. Ham, “The (un)broken promise of agroforestry: a case study of improved fallows in Zambia,” *Environ. Dev. Sustain.*, vol. 22, no. 8, pp. 8247–8260, 2020,

doi: 10.1007/s10668-019-00564-5.

[97] R. L. Roothaert and R. T. Paterson, “Recent work on the production and utilization of tree fodder in East Africa,” *Anim. Feed Sci. Technol.*, vol. 69, no. 1–3, pp. 39–51, 1997, doi: 10.1016/S0377-8401(97)81621-5.

[98] S. Bunma and H. Balslev, “A Review of the Economic Botany of Sesbania (Leguminosae),” *Bot. Rev.*, vol. 85, no. 3, pp. 185–251, 2019, doi: 10.1007/s12229-019-09205-y.

[99] I. Baltenweck, D. Cherney, Al. Duncan, E. Eldermire, E. Tandi Lwoga, R. Labarta, E. James Oburu Rao, S. Staal and N. Teufel, “A scoping review of feed interventions and livelihoods of small-scale livestock keepers,” *Nat. Plants*, vol. 6, no. 10, pp. 1242–1249, 2020, doi: 10.1038/s41477-020-00786-w.

[100] F. Place, R. Roothaert, L. Maina, S. Franzel, J. Sinja, and J. Wanjiku, *The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research*. p. 47. Nairobi, Kenya.: p. 47. Nairobi, Kenya., 2009.

[101] A. Mekoya, S. J. Oosting, S. Fernandez-Rivera, S. Tamminga, and A. J. Van der Zijpp, “Effect of supplementation of Sesbania sesban to lactating ewes on milk yield and growth rate of lambs,” *Livest. Sci.*, vol. 121, no. 1, pp. 126–131, Mar. 2009, doi: 10.1016/j.livsci.2008.06.002.

[102] K. J. Peters, “Nutritional Value of Sesbania sesban,” Addis Ababa, Ethiopia., 1988. [Online]. Available: http://www.fadr.msu.ru/rodale/agsieve/txt/vol2/9/art6.html Nutritional.

[103] J. P. Robert and M. A. Abdel-Hamid, “Can the woodfuel supply in sub-Saharan Africa be sustainable? The case of N’Djaména, Chad,” *Energy Policy*, vol. 33, no. 3, pp. 297–306, 2005, doi: 10.1016/j.enpol.2003.08.001.

[104] R. A. Swinkels, S. Franzel, K. D. Shepherd, E. Ohlsson, and J. K. Ndufa, “The Adoption Potential of Short Rotation Improved Tree Fallows: Evidence from Western Kenya.,” in *Trees on the farm: assessing the adoption potential of agroforestry practices in Africa*, S. Franzel and S. J. Scherr, Eds. CABI Publishing in association with the International Centre for Research in Agroforestry, 2002, pp. 65–86.

[105] E. B. Adelanwa and M. O. Tijani, “Performance of Cajanus cajan [l.] millsp. and Sesbania sesban as cooking fuel,” *J. Biosci. Biotechnol. Discov.*, vol. 1, pp. 1–5, 2016, doi: 10.31248/JBBD2016.005.

[106] A. K. Gupta, S. W. Su, and Z. S. Chen, “Heavy-Metal bioavailability and Chelate mobilization efficiency in an assisted phytoextraction process by Sesbania sesban (L.) Merr.,” *Commun. Soil Sci. Plant Anal.*, vol. 42, no. 2, pp. 231–245, 2011, doi: 10.1080/00103624.2011.535073.

[107] T. H. Dan and H. Brix, “Growth responses of the perennial legume Sesbania sesban to NH4 and NO3 nutrition and effects on root nodulation,” *Aquat. Bot.*, vol. 91, no. 3, pp. 238–244, 2009, doi: 10.1016/j.aquabot.2009.07.004.

[108] T. H. Dan, L. N. Quang, N. H. Chiern, and H. Brix, “Treatment of high-strength wastewater in tropical constructed wetlands planted with Sesbania sesban : Horizontal subsurface flow versus vertical downflow,” *Ecol. Eng.*, vol. 37, no. 5, pp. 711–720, 2011, doi: 10.1016/j.ecoleng.2010.07.030.

[109] P. C. Nwilo, D. N. Olayinka, C. J. Okolie, E. I. Emmanuel, M. J. Orji, and O. E. Daramola, “Impacts of land cover changes on desertification in northern Nigeria and implications on the Lake Chad Basin,” *J. Arid Environ.*, vol. 181, no. March, p. 104190, 2020, doi: 10.1016/j.jaridenv.2020.104190.

[110] E. Rukangira, “Medicinal Plants and Traditional Medicine in Africa: Constraints and Challenges,” *Conserv. Africa Int. Sustain. Dev. Int.*, pp. 179–184, 2001, [Online]. Available: https://www.semanticscholar.org/paper/Medicinal-Plants-and-Traditional-Medicine-in-Africa/7b6f7ffe3a8fb509450ab0c52500f6dc36f72667.

[111] J. H. C. Ribeiro, C. R. Fonseca, and F. A. Carvalho, “The woody vegetation of quartzite soils in a mountain landscape in the atlantic forest domain (south-eastern Brazil): Structure, diversity and implications for conservation,” *Edinburgh J. Bot.*, vol. 74, no. 1, pp. 15–32, 2017, doi: 10.1017/S096042861600024X.

[112] F. Bucar, A. Wube, and M. Schmid, “Natural product isolation-how to get from biological material to pure compounds,” *Nat. Prod. Rep.*, vol. 30, no. 4, pp. 525–545, 2013, doi: 10.1039/c3np20106f.

[113] B. David, J. L. Wolfender, and D. A. Dias, “The pharmaceutical industry and natural products: historical status and new trends,” *Phytochem. Rev.*, vol. 14, no. 2, pp. 299–315, 2015, doi: 10.1007/s11101-014-9367-z.

[114] S. Mosier, S. Carolina Córdova, and G. Philip Robertson, “Restoring Soil Fertility on Degraded Lands to Meet Food, Fuel, and Climate Security Needs via Perennialization,” *Front. Sustain. Food Syst.*, vol. 5, no. October, pp. 1–18, 2021, doi: 10.3389/fsufs.2021.706142.