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Phytochemical Characterization and Antibacterial Potential of Senna alata (L.) Roxb. with Implications for Sustainable Medicinal Plant Utilization

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Abstract- Senna alata (L.) Roxb. is an important medicinal plant traditionally recognized for its therapeutic and antimicrobial properties. The present study investigated the phytochemical and biochemical profile and antibacterial potential of S. alata, with reference to sustainable utilization and SDG 13 – Climate Action. Preliminary phytochemical screening revealed the presence of alkaloids, flavonoids, phenols, tannins, anthraquinones, glycosides, steroids, saponins and other bioactive constituents. GC–MS analysis identified 18 phytochemical compounds, while FTIR analysis confirmed characteristic functional groups including O–H, N–H, C–H, C–O and C–N. The methanolic leaf extract exhibited antibacterial activity against Escherichia coli, Staphylococcus epidermidis, Klebsiella sp., Staphylococcus aureus and Pseudomonas aeruginosa, with inhibition zones ranging from 7–16 mm. The highest activity was observed against S. aureus and Klebsiella sp. The findings highlight the phytochemical richness and promising antibacterial potential of S. alata and support its responsible utilization as a valuable medicinal plant resource. Sustainable cultivation and conservation of such plant resources may further contribute to biodiversity protection and the broader objectives of SDG 13 – Climate Action.

Keywords- Senna alata; Phytochemical screening; GC–MS; FTIR; Methanolic leaf extract; Antibacterial activity; Medicinal plant; Bioactive compounds; Sustainable utilization; Biodiversity conservation; SDG 13; Climate Action.

I. Introduction

Candlestick Senna (Senna alata) is a small shrub or tree native to Central and South America, widely grown in warm regions. It produces striking, candle-like yellow flowers in late summer and attracts pollinators, especially sulphur butterflies. The plant is also traditionally recognized for its antifungal properties and medicinal potential.

S. alata(L) Roxb is a medicinal ornamental plant. Studies have reported the therapeutic use of S. alata (L) Roxb leaves in such diseases as liver problems, abdominal pain, and constipation (Hennebelle et al., 2009). It has also been utilized in the treatment of dermatological diseases such as eczema, athlete's foot, inflamed skin, rashes on skin, as well as ringworm (from where the name 'ringworm shrub' was gotten) (Jaimeson et al., 2008). It is used to manage diabetes and hyperglycaemia (Abo et al., 2008). Its antiviral, antibacterial and antifungal activities have been proven, as well as its laxative properties (Hennebelle et al., 2009).

The plant extracts were found to be rich in flavonoids, terpenoids and steroids, and phenolics. The plant extracts exhibited antibacterial activity with minimum inhibitory

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concentrations (MICs) ranging from 0.3125 to 2.5 mg/mL. (Vincent Ngouana, et al., 2025).

Stem bark of S. alata L. is used to treat fungal infections such as ringworm. It is a common ingredient in soaps, shampoos, and lotions because of its antifungal properties. The ethanolic extract of the stem bark of S. alata L. could be fungistatic; it inhibits fungal multiplication without necessarily killing them. The ethanolic extract may also be against protein-synthesizing machinery or against an enzyme involved in nucleic acid synthesis (Dawn, 2005). S. alata L. is locally used in Nigeria in the treatment of several infections, which include ringworm and parasitic skin diseases. Cassia alata has been reported to contain anthraquinones and the methanol fractions were found to be active against Aspergillus flavus (Ogunde and Elu Joba, 1993; Omoyele et al., 2005). Most of the drugs today are reported from natural sources or semi-synthetic derivatives of natural products and used in traditional systems of medicine (Sukanya et al., 2009).

SDG 13 Climate Action and Relevance of Senna alata

The present study on Senna alata is also relevant to Sustainable Development Goal 13 (SDG 13): Climate Action, which emphasizes strengthening actions to address climate change and its impacts. Medicinal plants such as S. alata form an important component of plant biodiversity and can contribute to climate-resilient and sustainable ecosystems. As a hardy plant adapted to warm climatic conditions, S. alata has potential value in supporting the conservation and sustainable utilization of medicinal plant resources under changing environmental conditions.

The phytochemical and pharmacological properties identified in S. alata, particularly its antimicrobial potential, highlight the importance of conserving medicinal plant biodiversity for future generations. Sustainable cultivation and utilization of medicinal plants can encourage the maintenance of green cover, contribute to ecosystem stability, and promote the responsible use of natural resources. The development of plant-based antimicrobial resources may also support the exploration of environmentally friendly alternatives to excessive dependence on synthetic chemical products.

Climate change can influence plant growth, distribution, phytochemical production, and therapeutic properties. Therefore, documenting the phytochemical characteristics and biological activities of medicinal plants such as S. alata is important for establishing baseline information for their future conservation and sustainable use. Integrating medicinal plant research with climate-conscious cultivation, biodiversity conservation, and sustainable harvesting practices can contribute to the broader objectives of SDG 13 – Climate Action.

II. Materials and Method

Collection and Preparation of Plant Extract

The plant Senna alata was collected from its natural habitat in Madurai, Tamil Nadu, India. The leaves and flowers were thoroughly cleaned, washed with distilled water, and shade-dried. The dried plant material was pulverized into a fine powder and stored in airtight, moisture-free containers until further analysis. A total of 100 g of the powdered plant material was extracted with 500 mL of ethanol in a Soxhlet apparatus for 6–8 hours at a controlled temperature. The resulting ethanolic extract was

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subsequently used for fluorescence analysis, phytochemical screening, GC–MS, FTIR analysis, and antibacterial activity studies.

Preliminary Phytochemical Screening

A series of qualitative chemical tests was conducted to identify the major phytochemical constituents and establish the chemical profile of the respective solvent extracts. The solvents were subjected to different tests to detect various phytoconstituents present in them (Brindha et al., 1981; Anonymous, 1990; Lala, 1993).

GC-MS Analysis

GC–MS analysis of Senna alata leaf powder was carried out using an Agilent Technologies GC-7820A gas chromatograph coupled with an MS-5977E mass spectrometer, equipped with an HP-5MSD capillary column (30 m × 0.25 mm i.d.; 0.25 µm film thickness). The analysis was performed under electron ionization (EI) at 70 eV, using high-purity helium (99.995%) as the carrier gas at a flow rate of 1.2 mL/min. The oven temperature was initially maintained at 50 °C and subsequently programmed to increase to 250 °C at a rate of 3 °C/min, followed by a final hold of 10 min. A 1% extract, appropriately diluted with the corresponding solvent, was injected in splitless mode. The resulting mass spectra were used for compound identification, and the relative abundance of each compound was determined from its percentage contribution to the total chromatographic peak area.

FTIR Analysis

The extracts of Senna alata were subjected to Fourier Transform Infrared (FTIR) spectroscopic analysis to identify the characteristic functional groups present. The extracts were centrifuged at 3000 rpm for 10 min and subsequently filtered through Whatman No. 1 filter paper using a high-pressure vacuum pump. The filtered extracts were diluted tenfold (1:10) with the respective solvent. FTIR spectra were recorded using a Perkin-Elmer spectrophotometer equipped with an ATR system over the spectral range of 400–5000 cm^{-1}. The characteristic absorption peaks were recorded and interpreted based on their corresponding functional groups. Each analysis was performed in duplicate to ensure reproducibility and spectral confirmation.

Antibacterial Assay

The antibacterial activity of the plant extract was evaluated against Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli, Pseudomonas aeruginosa, and Klebsiella sp. The bacterial cultures were grown in nutrient broth at 37°C for 24 h, and the antibacterial activity was assessed by the agar well-diffusion method (Bauer et al., 1996). The standardized inoculum was uniformly spread on Mueller–Hinton agar plates, and the extract was tested at 100, 150, and 200 µg/milk Methanol (50 µg/mL) served as the negative control, while streptomycin was used as the standard antibiotic. Antibacterial activity was determined by measuring the zones of inhibition.

III. Result & Discussion

Loss on drying

The fresh leaves and the loss on drying of Senna alata are shown in Table 1). The fresh leaf weight and the loss of weight on drying the leaves were 5.03% and 2.07%, respectively. There was a decrease in the weight after drying the leaves.

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Table (1): Loss on drying (Moisture content) %

Particulars	*Senna alata*	
Loss on drying%	Fresh leaves	Dried leaves
	5.03±0.4	2.07±0.4

Ash and extractive values

The ash and extractive values of Senna alata are presented in Table 2. The total ash, acid-insoluble ash, and water-soluble ash values were 2.06%, 1.83%, and 0.37%, respectively. The higher water-soluble extractive value indicates the presence of appreciable amounts of water-soluble constituents such as sugars, organic acids, and inorganic compounds. The total ash value reflects the mineral and earthy matter present in the plant material, while extractive values provide its soluble phytochemical constituents.

Table (2): Ash value of the leaves of Senna alata

S. No	Type of Ash	Ash value (%)
		Senna alata (Whole plant extract)
1.	Total ash value	2.06 gm
2.	Water soluble ash	1.83 gm
3.	Acid insoluble ash	1.35 gm
3.	Sulphated ash	0.37 gm

IV. Fluorescent Analysis

The fluorescence characteristics of Senna alata leaf powder under daylight and UV light are presented in Table 3. The sample exhibited distinct fluorescence color changes with acidic and alkaline reagents. Under UV light, seven green, two dark green, one red-green, one dark green, and one brown fluorescence colors were observed, while daylight showed three green, three dark green, two green, and one dark brown color. These variations indicate the presence of phytoconstituents and support the fluorescence analysis as an important parameter in the pharmacogenetic evaluation and identification of plant materials (Alagar et al., 2014; Gupta, 2006; Ansari, 2006).

Table (3): Fluorescence analysis of Senna alata

S. No	**Treatment**	**UV light**	**Day light**
1.	Powder as such	Dark Green	Light Green
2.	Powder + NaOH	Green Fluorescence	Dark Fluorescence
3.	Powder + 1 N NaOH	Green Fluorescence	Green Fluorescence
4.	Powder + 1 N HCL	Green Fluorescence	Green

5.	Powder + H_2So_4(1:1)	Red Green Fluorescence	Light brown
6.	Powder + HNO_3(1:1)	Green Fluorescence	Green
7.	Powder + NH_3	Green Fluorescence	Light brown
8.	Powder + Iodine	Green Fluorescence	Dark Green
9.	Powder + 5% $FeCL_3$	Dark Green Fluorescence	Green Fluorescence
10.	Powder + Acetone	Brown	Green Fluorescence
11.	Powder + Methanol	Green Fluorescence	Dark brown
12.	Powder + $CHCL_3$	Dark Green	Dark Green

Preliminary phytochemical screening

Preliminary phytochemical screening of Senna alata leaves in three extracts revealed the presence of carbohydrates, proteins, alkaloids, flavonoids, phenols, tannins, anthraquinones, glycosides, steroids, volatile oils, cardiac glycosides, xanthoproteins, catechins, and tannins. The presence of alkaloids, flavonoids, and phenolics indicates the richness of the plant in bioactive secondary metabolites. These phytoconstituents may contribute to the plant's antimicrobial and therapeutic properties and provide a basis for further chromatographic and pharmacological investigations.

Phytochemicals are widely recognized as the bioactive constituents underlying the therapeutic applications of traditional herbal medicines, which continue to be practiced in various parts of the world (Lalitha and Jayanthi, 2012). The type, quantity, and composition of phytochemicals may vary considerably among different plant parts. These compounds are naturally synthesized and accumulated throughout the plant, including the bark, leaves, stems, roots, flowers, fruits, and seeds. Consequently, different parts of a plant may contain distinct bioactive constituents that contribute to its medicinal properties (Tiwari et al., 2011).

Table (4): Phytochemical screening of the leaves of Senna alata

S. No	Test	Methanol extract	Acetone extract	Aqueous extract
1.	Protein	-	+	+
2.	Carbohydrate	-	-	+
3.	Alkaloid	+	+	+
4.	Flavonoid	+	+	+
5.	Phenol	+	+	+
6.	Tannin	+	+	+
7.	Anthraquinone	-	+	+
8.	Glycoside	-	+	+
9.	Steroid	+	+	-
10.	Volatile oil	-	+	+
11.	Cardiac glycosides	-	+	+
12.	Xanthoprotein	+	+	+
13.	Catechin	-	+	+

14.	Tannins	+	+	+

V. GCMS ANALYSIS

GC–MS analysis of the Senna alata extract revealed several chromatographic peaks distributed across the retention-time range of approximately 2.824–18.000 min. The major chromatographic response was observed at approximately 8.9 min, while prominent peaks were also recorded at 16.501, 17.471 and 18.000 min. The variation in retention times indicates the separation of chemically diverse constituents present in the extract. The intensity of individual peaks reflects the relative detector response of the corresponding compounds, with prominent peaks indicating greater chromatographic abundance.

The eighteen compounds identified are: L-Glucose, 6-deoxy-3-O-methyl, 1-Pentanethiol, 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl, Benzofuran, 2,3-dihydro, Benzene, propyl-, Resorcinol, Cyclohexanone, 4-methylidene, 4(1H)-Pyrimidinone, 2-methyl, Diphenylamine, Hydrazinecarboxamide, N,N-diphenyl-, 1,3-Dioxane, 2-pentadecyl-, 1-Butene, 1-(methylthio)-, (Z)-, 2-Amino-4-methyl-3-pyridinol, 4(1H)-Pyrimidinone, 2,6-dimethyl-, 9,12,15-Octadecatrienoic acid, 2 Methyl 8,11,14-heptadecatrienoate, 9,19-Cyclocholest-24-en-3-ol, 14-methyl-, acetate

Table (5): GCMS compounds identified in the methanol extract of Senna alata

S. No.	Compound	Molecular significance	Possible biological/pharmacological relevance
1	L-Glucose, 6-deoxy-3-O-methyl	Oxygenated sugar derivative	May contribute to the polar phytochemical fraction; biological significance requires confirmation
2	1-Pentanethiol	Sulfur-containing volatile compound	Sulfur compounds may contribute to antimicrobial/defensive properties
3	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl	Oxygenated heterocyclic compound	Associated with antioxidant and bioactive properties in plant-derived extracts
4	Benzofuran, 2,3-dihydro	Oxygen-containing aromatic heterocycle	Benzofuran derivatives are reported to possess diverse biological activities
5	Benzene, propyl-	Aromatic hydrocarbon	Mainly indicates the presence of volatile/aromatic constituents
6	Resorcinol	Phenolic compound with two hydroxyl groups	Phenolic structure may contribute to antioxidant and antimicrobial activity

S. No.	Compound	Molecular significance	Possible biological/pharmacological relevance
7	Cyclohexanone, 4-methylidene	Oxygenated cyclic ketone	May contribute to the volatile bioactive fraction
8	4(1H)-Pyrimidinone, 2-methyl	Nitrogen-containing heterocycle	Heterocyclic compounds can possess diverse biological activities
9	Diphenylamine	Nitrogen-containing aromatic compound	Reported in biological/chemical studies, but its specific role in *S. alata* requires confirmation
10	Hydrazinecarboxamide, N,N-diphenyl-	Nitrogen-rich organic compound	May contribute to the detected bioactive chemical profile; identification should be library-confirmed
11	1,3-Dioxane, 2-pentadecyl-	Long-chain oxygenated compound	May contribute to membrane-associated and antimicrobial properties
12	1-Butene, 1-(methylthio)-, (Z)-	Sulfur-containing unsaturated compound	Sulfur-containing compounds may have antimicrobial potential
13	2-Amino-4-methyl-3-pyridinol	Nitrogen- and oxygen-containing heterocycle	Pyridinol derivatives have potential biological activity
14	4(1H)-Pyrimidinone, 2,6-dimethyl-	Nitrogen-containing heterocyclic compound	May contribute to the biological diversity of the extract
15	9,12,15-Octadecatrienoic acid	Polyunsaturated fatty acid (α-linolenic acid)	Important plant fatty acid; associated with membrane structure and several biological functions
16	9,12,15-Octadecatrienoic acid	Polyunsaturated fatty acid	Same compound reported at another chromatographic entry; should be checked for duplication/identification
17	2-Methyl 8,11,14-heptadecatrienoate	Unsaturated fatty-acid ester	May contribute to the lipid fraction and biological properties of the extract

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S. No.	Compound	Molecular significance	Possible biological/pharmacological relevance
18	9,19-Cyclocholest-24-en-3-ol, 14-methyl-, acetate	Sterol-related compound	Sterol derivatives may contribute to membrane-related and other biological activities

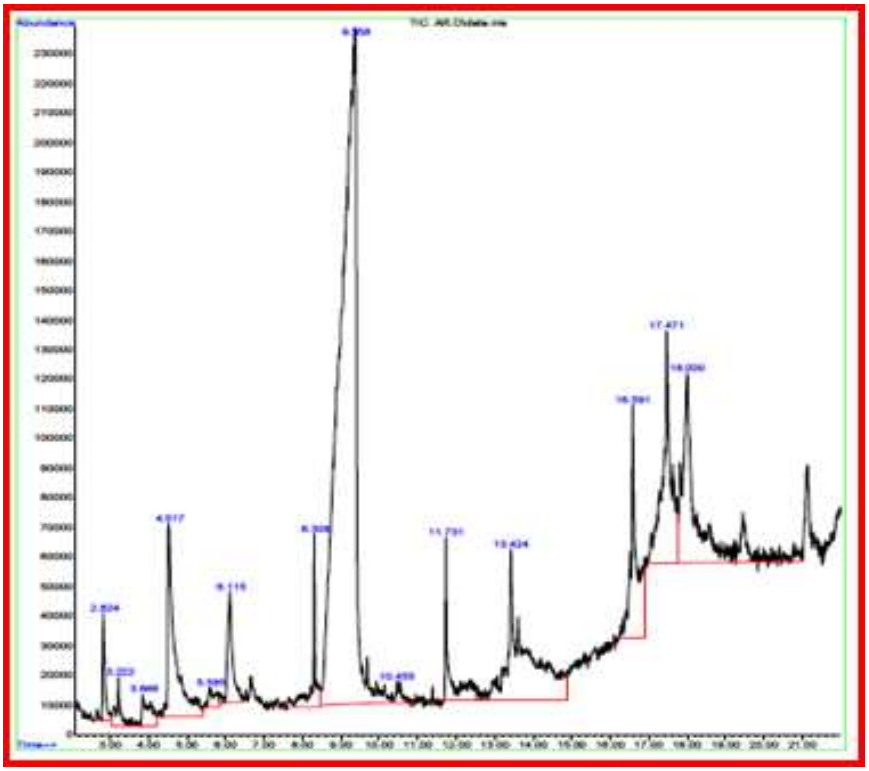

Fig. (1): GC-MS chromatogram of the whole plant methanolic extract of Senna alata

FTIR Analysis

The FT-IR spectrum was used to identify the functional groups of the active components present in the extract based on the peak values in the region of IR radiation. When the extract was passed into the FT-IR, the functional groups of the components were separated based on their peak ratios. The results of FT-IR analysis confirmed the presence of N-H, O-H, C=C, C-H, C-O and CH3 functional groups (Figure 2 and Table 6). FTIR spectroscopy has been proven to be a reliable and sensitive method for the detection of biomolecular composition.

FTIR analysis of Senna alata revealed a diverse range of functional groups, indicating the chemically complex nature of the extract. Prominent absorptions at 3414.73 and 3844.83 cm^{-1} indicated hydroxyl groups associated with alcohols and phenolic compounds, while the peak at 1239.18 cm^{-1} suggested C–O-containing constituents

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such as alcohols, ethers and esters. Peaks corresponding to C–H, C–C and C–N vibrations further indicated the presence of aliphatic, aromatic and nitrogen-containing compounds. The observed functional groups support the phytochemical screening and GC–MS findings and provide evidence for the presence of structurally diverse bioactive constituents in S. alata. These constituents may collectively contribute to the biological properties, including the antibacterial activity, observed in the present study.

Table (6): The functional groups of Senna alata

Wavenumber (cm^{-1})	Interpretation	Significance
3844.83	O–H, free hydroxyl	Indicates relatively free hydroxyl groups
3414.73	O–H stretching	Strong evidence for alcohols/phenols and hydrogen-bonded hydroxyl groups
3271.05	≡C–H / N–H region	Indicates a possible terminal alkyne or N–H-containing constituent; assignment needs caution
3079.14	Aromatic C–H	Supports the presence of aromatic compounds
2852.52	Aliphatic C–H	Indicates alkane/aliphatic hydrocarbon chains
2361.67	C≡N according to your table	Should be interpreted cautiously; this region can also be associated with atmospheric CO_2
1741.60	Carbonyl region	Strongly suggests C=O-containing compounds such as esters, aldehydes or ketones; this is an important peak
1624.92	C=C / N–H region	May indicate unsaturation or nitrogen-containing compounds
1510.16	N–O / aromatic region	May indicate nitro-type or aromatic structural features
1460.98	C–H bending	Supports aliphatic hydrocarbon groups
1410.83	Aromatic C–C	Supports aromatic ring structures
1387.69	C–H deformation	Associated with aliphatic groups
1319.22	C–N	Supports nitrogen-containing compounds
1239.18	C–O	Indicates alcohol, ether, ester or related oxygen-containing compounds

Wavenumber (cm^{-1})	Interpretation	Significance
1195.78–1099.35	C–H/C–N/C–O region	Represents fingerprint-region vibrations of diverse organic constituents
753.15	C–Cl according to your table	Fingerprint-region absorption; assignment should be interpreted cautiously
642.25	≡C–H bending	Possible alkyne-related vibration
603.68	C–Br according to your table	Low-frequency fingerprint-region absorption

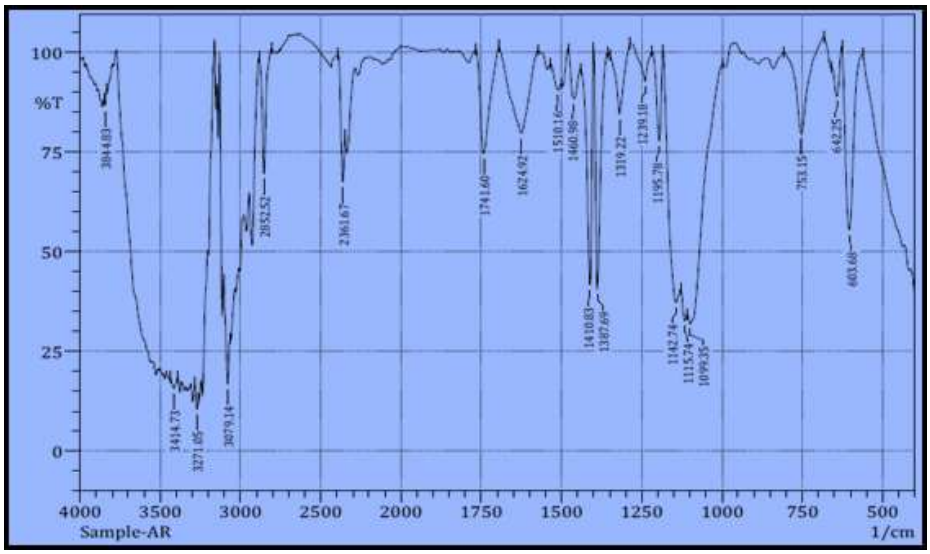

Fig. (2): FTIR Chromatogram of Senna alata

VI. Antibacterial Activity

The antibacterial efficacy of Senna alata leaf extract was evaluated using the well-diffusion method against Escherichia coli, Staphylococcus epidermidis, Klebsiella sp., Staphylococcus aureus, and Pseudomonas aeruginosa. The methanolic extract was tested at concentrations of 50, 100, and 150 µL. All tested bacterial strains showed sensitivity to the extract, with inhibition zones ranging from 7–16 mm. E. coli showed zones of 8, 12, and 14 mm; S. epidermidis 9, 14, and 12 mm; Klebsiella sp. 8, 12, and 16 mm; S. aureus 12, 10, and 16 mm; and P. aeruginosa 7, 12, and 13 mm, respectively. Overall, the highest antibacterial activity was observed against S. aureus and Klebsiella sp., demonstrating the promising antibacterial potential of S. alata leaves.

Anthraquinone and flavonoid glycosides detected in S. alata extracts significantly inhibited the growth of E. coli and S. aureus, with ZOI ranging from 9.7 to 14.8 mm (Khan et al., 2001; Somchit et al., 2003). The plant secondary metabolites contributed to the pronounced wound healing and antibacterial and antifungal activities (Sule et al.,

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2010; Onwuliri, 2004). Different parts of the plant S. alata are reported in folk medicine as therapeutic substances for the remediation of various diseases and infections. The extracts and isolated compounds displayed pronounced pharmacological activities (Oluwole et al., 2020).

Table (7): Antimicrobial activity of Senna alata extract (Ethanol sample)

S. No	Pathogens	Control	Antibiotic	Concentrations(µl)		
				50µl	100µl	150µl
1.	*Escherichia coli*	0	18	8 mm	12 mm	14 mm
2.	Staphylococcus epidermis	0	18	9 mm	14 mm	12 mm
3.	Klebsiella	0	18	8 mm	12 mm	16 mm
4.	Staphylococcus aureus	0	18	12 mm	10 mm	16 mm
5.	*Pseudomonas aeruginosa*	0	18	7 mm	12 mm	13 mm

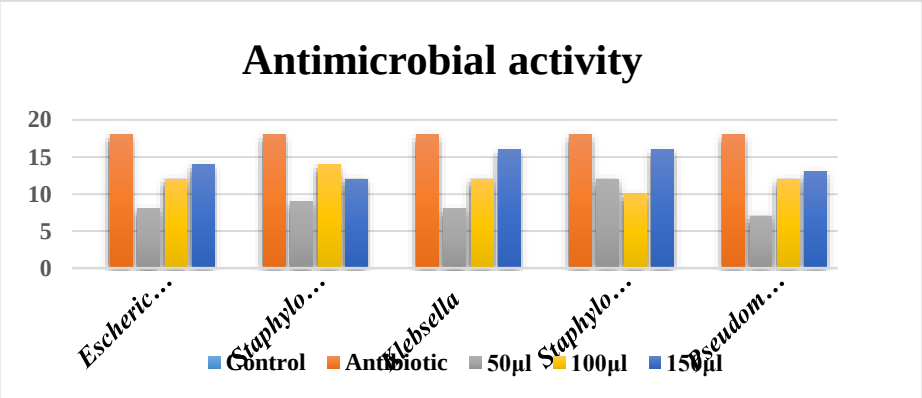

Fig. (3) Graphical representation of Antimicrobial Activity

It is clear from the bar graph representing the estimated activity of the Cassia auriculata whole plant in comparison with the control (Fig. 7) that it exhibits significant activity (≈ 80 % as that of the control) against antimicrobial activity and hence the whole plant can be an excellent anti-diabetic agent.

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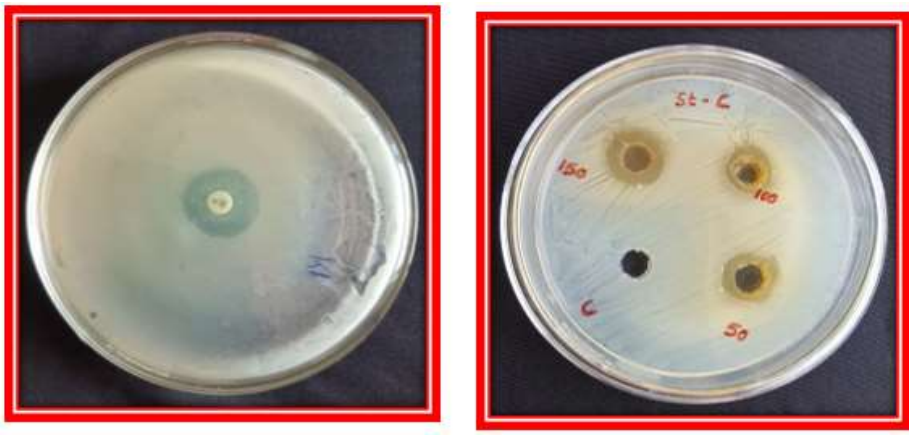

Fig. (4) Antibacterial Activity of Senna alata

VII. Conclusion

The present study demonstrates that Senna alata (L.) Roxb. is a phytochemically rich medicinal plant with promising antibacterial potential and considerable relevance for sustainable medicinal plant utilization. Preliminary phytochemical screening revealed the presence of diverse bioactive constituents, including alkaloids, flavonoids, phenols, tannins, anthraquinones, glycosides, steroids, volatile oils, and other secondary metabolites. GC–MS analysis further identified 18 phytochemical compounds, representing chemically diverse constituents such as phenolic compounds, heterocyclic compounds, fatty acids, sulfur-containing compounds, and sterol-related compounds. FTIR analysis supported these findings by confirming characteristic functional groups, including O–H, N–H, C–H, C=O, C–O, C–N and aromatic groups, indicating the complex biochemical composition of the plant extract.

The antibacterial assay demonstrated that the leaf extract was active against all the tested bacterial strains, namely Escherichia coli, Staphylococcus epidermidis, Klebsiella sp., Staphylococcus aureus and Pseudomonas aeruginosa, with inhibition zones ranging from 7 to 16 mm. The comparatively higher activity observed against S. aureus and Klebsiella sp. indicates the promising antibacterial potential of S. alata leaves. These findings provide scientific support for the traditional medicinal importance of the plant and establish a basis for further investigation of its bioactive constituents.

From the perspective of SDG 13 – Climate Action, sustainable cultivation and responsible harvesting of S. alata can support medicinal plant conservation, maintain green cover and biodiversity, and promote the sustainable use of natural resources. Encouraging plant-based and environmentally responsible alternatives can also help reduce unnecessary dependence on synthetic chemical products.

Thus, conservation, climate-resilient cultivation and sustainable utilization of S. alata can contribute simultaneously to medicinal resource development, biodiversity conservation and climate-conscious sustainable development, highlighting its relevance to SDG 13.

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