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Anthelmintic and Phytochemical Studies of Ethanolic Extract of Stem Bark of *Alangium salvifolium*

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Abstract: Helminth infections cause many acute and chronic illnesses in human beings and in cattle, particularly in tropical and subtropical areas. Due to drug resistance and high costs of conventional anthelmintic drugs, herbal remedies are being evaluated as alternative anthelmintics for controlling these parasites. Researcher in the field of bioscience shows great interest in medicinal plants, as most of the drug industries rely on medicinal plants for the production of pharmaceutical compounds. This study aimed to screen the phytocompounds by Gas Chromatography and Mass Spectroscopy (GC-MS) and to determine the anthelmintic activity of ethanolic extract of stem bark of *Alangium salvifolium*. In this study, *in vitro* experiments were conducted to evaluate the potential anthelmintic effects of ethanolic extracts of the stem bark of *Alangium salvifolium* (at doses of 10 to 50 mg/ml) against the Eritrean adult earthworm *Pheretima posthuma* (an Annelid; earthworms were used for evaluating the anthelmintic activity which possess similarity with human intestinal parasites), with albendazole used as a reference standard. All tested concentrations demonstrated anthelmintic activity against the selected earthworms, with the maximum effect observed at the highest concentration of 50 mg/ml. The GC-MS analysis showed twenty–nine compounds including 4-Decene, 2,2-dimethyl-, (e)- (2.52%); 3,6,9-Trioxadecanoic acid, TBDMS derivative (0.99%); 1-[(Trimethylsilyl)oxy]propan-2-ol (2.12%); 1,1,3-Triethoxybutane (5.98%); Glycerin (69.91%); 1-Tridecene (0.28%); Cyclohexane, octyl- (0.07%); Propionic acid, 3-iodo-, octadecyl ester (1.76%); 1-Pentadecene (0.64%); Squalene (0.21%) and Diethyl phthalate (1.33%) in the ethanolic extract of *Alangium salvifolium*. The anthelmintic activity of ethanolic extract of stem bark of *Alangium salvifolium* may be attributed to the secondary metabolites present in the plant. These results support the use of *Alangium salvifolium* in various disorders. There is need for further studies to obtain the active principle of the extract as well as to get their exact mechanism of action in different disorders including anthelmintic activity.

Keywords: *Alangium salvifolium*, GC-MS, Secondary metabolites, Ethanolic extract, Stem bark, Anthelmintic activity

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Introduction

Plants are one of the richest sources of bioactive compounds, widely used in traditional and modern medicine for their therapeutic potential (Singh, 2020). These bioactive constituents, commonly known as phytocompounds, include alkaloids, flavonoids, terpenoids, tannins, glycosides, and phenolics, which are known to exhibit diverse pharmacological properties such as antimicrobial, antioxidant, anti-inflammatory, anticancer, and hepatoprotective effects (Balunas and Kinghorn, 2005). Unlike synthetic drugs, which may cause side effects or drug resistance, the herbal medicines derived from plant secondary metabolites are considered relatively safer, more accessible, and culturally accepted in many parts of the world (Ekor, 2014).

Helminthic infections represent a significant public health challenge. The cumulative medical, educational, and economic burdens of these diseases provide a compelling rationale for a coordinated global initiative against parasitic worms (Hotez, 2021). Helminths is a broad term for worm-like invertebrates usually including parasitic worms in the phylum Platyhelminthes (flatworms) and Nematoda (roundworms). There are many chemical entities for controlling worm infections, among these drugs albendazole, oxamniquine, praziquantel and ivermectin were developed to treat helminthiasis (Hotez, 2021). The anthelmintic resistance and the high cost of anthelmintic drugs led to discovery of alternative anthelmintic drugs from natural sources. The indiscriminate use of conventional antimicrobials has led to the emergence of multidrug-resistant pathogens and adverse side effects in humans, including hypersensitivity, immunosuppression, and systemic toxicity. These challenges have driven the search for novel anthelmintic agents derived from botanical sources. Herbal medicines remain the primary source of healthcare in many developing nations, favored for their cultural acceptability, biological compatibility, and reduced risk of adverse side effects.

Alangium salvifolium (L.f) Wang (family Alangiaceae) is a traditionally used medicinal plant in Unani, Ayurveda and Siddha medicine system (Kirtikar and Basu, 2001). It is found in tropical and subtropical regions of Asia. Plant parts including roots, bark, leaves, and fruits are reported to have medicinal value (Ratra and Gupta, 2015). The bark of *A. salvifolium* is particularly significant, being traditionally employed in the treatment of rheumatism, leprosy, piles, paralysis, skin disorders, and inflammatory conditions (Chopra *et al.*, 1956).

Phytochemical studies of *A. salvifolium* bark have showed the presence of various bioactive compounds such as alkaloids (Alangine, Alangicine and Tubulosine), flavonoids, saponins, tannins, and phenolics, which may contribute to its wide range of pharmacological activities (Panara *et al.*, 2016). Experimental studies have reported its analgesic, anti-inflammatory, antimicrobial, antioxidant, antidiabetic, and anticancer properties, which justify its importance in traditional medicine and highlight its potential for new drug discovery (Rao *et al.*, 2012).

With the growing interest in natural products and the limitations of synthetic drugs, phytochemical profiling of medicinal plants has become a crucial step in validating traditional knowledge and identifying novel bioactive molecules (Newman and Cragg, 2020). Gas Chromatography–Mass Spectrometry (GC-MS) are invaluable in detecting and characterizing the complex mixture of compounds in medicinal plants, providing scientific evidence to support their therapeutic applications (Altemimi *et al.*, 2017).Therefore, an in-depth phytochemical analysis of the stem bark of *Alangium salvifolium* is essential to scientifically substantiate its ethnomedicinal relevance and explore its potential as a source of novel phytocompounds for pharmaceutical applications. Based on the above said points in view, this study was aimed to determine the anthelmintic activity and to screen the phytocompounds of ethanolic extract of stem

bark of *Alangium salvifolium* by Gas Chromatography and Mass Spectroscopy (GC-MS).

Materials and Methods

Collection of plant materials

The stem bark of *Alangium salvifolium* was collected from banks of Cauvery near Kumbakonam, Tamil Nadu India. The plant was identified by Dr. R. Murugan, Department of Botany, Government Arts College (Autonomous), Kumbakonam, Tamil Nadu, India. The plant materials were washed under running tap water and finally with distilled water to remove any dirt particles from it. For 15 days the plant materials were shade dried at room temperature and made to fine powder. The powdered materials were stored in air tight containers until use.

Preparation of plant extracts

Powdered materials of about 100 g of stem bark was taken and extracted by Soxhlet apparatus with ethanol at 70 °C. After 48 h of extraction, the extracts were sequentially filtered, first using cheesecloth and then Whatman No. 1 filter paper. The extracts were concentrated in an oven at 40–45 °C until the solvent completely evaporated, yielding a dark brown residue. The residues were placed into separate airtight containers and maintained at 4 °C until the time of use

Worm Collection and Authentication

Pheretima posthuma (Indian earthworms, Annelida) were collected near the areas of pond with the size of 6 to 8 cm at Government Arts College (Autonomous), Kumbakonam, Tamil Nadu, India and authenticated from the Department of Zoology, Government Arts College (Autonomous), Kumbakonam, Tamil Nadu, India.

In this study earthworm was used for evaluating the anthelmintic activity of the plant extract as the earthworm possess anatomical and physiological similarity to human intestinal roundworm (Choudhary *et al.*, 2021; Manke *et al*., 2024). In past few investigators have also used earthworms for testing anthelmintic activity of plant extracts (Shelke *et al*., 2020; Choudhary *et al.*, 2021; Mathias *et al.*, 2021; Manke *et al*., 2024; Saleh *et al.*, 2024; Bazán *et al.*, 2025; Sahu *et al.*, 2025; Kamsala *et al*., 2025; Vinciya *et al.*, 2025).

Anthelmintic Activity

Samples for the in vitro anthelmintic study were prepared by dissolving and suspending the extract in 100 ml of distilled water at concentrations of 10, 20, 30, 40 and 50 mg/ml. *In vitro* anthelmintic properties were observed in the ethanolic extract of *Alangium salvifolium* stem bark. The study assessed anthelmintic activity by applying the method of Ghosh *et al*. (2005) on adult *Pheretima posthuma* (Indian earthworm). Three groups of approximately equal sized Indian earthworms consisting of six earthworms in each group were released into 50 ml of desired formulation. Normal saline was administered to Group I, which served as the negative control; Group II was given various concentrations of an ethanolic extract derived from the stem bark of *Alangium salvifolium* and the positive control was Group III received standard drug albendazole (20 mg/ml). The time intervals leading to both paralysis and mortality were observed and documented for individual specimens. Worms were classified as paralyzed if they exhibited no movement except when vigorously shaken. When the worms lose their motility followed with fading away of their body colour death was concluded. The mean time to paralysis was noted, and the time of death of the worms was recorded after confirming they were unresponsive to vigorous shaking or dipped in normal saline and the results were expressed in comparison to the standard drug Albendazole (20 mg/ml).

GC-MS analysis

The phytochemical screening of the extracts of stem bark of *Alangium salvifolium* was carried out by GC-MS analysis by using the instrument Perkin Elmer Clarus 500. Capillary Column Elite-5MS help in obtaining the data and the following procedure was followed. Carrier gas (Helium (99.999%)) was used with a flow rate of 1 ml/min in the split mode (10:1). A 1 µl injection volume of the methanol

Table 1: *In vitro* anthelmintic activity of ethanolic extracts of stem bark of *Alangium salvifolium*

Concentration of extracts (mg/ml)	Time taken for paralysis (min)	Time taken for death (min)	Time between paralysis and death (min)
10	101.4 ± 2.5	138.8 ± 3.2	37.4 ± 4.1
20	102.6 ± 3.8	118.4 ± 2.7	15.8 ± 4.7
30	90.8 ± 3.5	105.1 ± 2.8	14.3 ± 4.5
40	82.8 ± 2.9	100.3 ± 2.4	17.5 ± 3.8
50	70.6 ± 2.1	90.5 ± 3.7	19.9 ± 4.3
Control (Normal saline)	-	-	-
Albendazole (20 mg/ml)	45.8 ± 2.4	58.4 ± 2.8	12.6 ± 3.7

sample solution was used, with the injector temperature maintained at 270 °C. GC oven temperature started at 110 °C and holding for 2 min and without holding it was raised to 200 °C at the rate of 10 °C/min. Holding was allowed at 280 °C for9 min with program rate of 5 °C/min [50 °C @8 °C/min to 150 °C (5 min)@ 8 °C/min to 250 °C (10 min)]. 200 °C was maintained at GC interface and Ion source temperature, The mass spectrum of compounds in the samples was obtained by electron ionization at 70 eV and it is detected in scan mode from 40-450 amu (atomic mass units). The analysis was performed using a 0.5 s scan interval, covering a fragment mass range of 40–450 Da.

Identification of components

Mass spectra obtained from an extract of *Alangium salvifolium* stem bark were interpreted using the National Institute of Standards and Technology (NIST) library database, which has over 62,000 patterns. The spectrum of the compound was compared with the spectrum of NIST library database. For the identification of compounds, the identity of the spectra above 95% was needed. The molecular weight, name, retention time, molecular formula and structure of compounds of the extract of stem bark was ascertained. The amount of each component relative percentage was calculated by comparing its average peak area with the total area. The spectrum of the unknown component was compared with the spectrum of the component stored in the NIST library using the Turbomass version 5.2.0. The NIST library database used in interpretation of GC-MS and the prediction of the biological activity of compounds was based on Dr. Duke's phytochemicals and ethnobotanical databases established by Dr. Jim Duke of the Agricultural Research Service, USDA.

Results

The *in vitro* anthelmintic activity of ethanolic extract of stem bark of *Alangium salvifolium* was studied and the results are presented in Table 1. The ethanolic extract of stem bark of *Alangium salvifolium* at 10 mg/ ml concentration showed paralysis time 101.4 ± 2.5 min and death time 138.8 ± 3.2 min, 20 mg/ml showed paralysis time 102.6 ± 3.8 min and death time 118.4 ± 2.7 min, 30 mg/ ml showed paralysis time 90.8 ± 3.5 min and death time 105.1 ± 2.8 min, 40 mg/ ml showed paralysis time 82.8 ± 2.9 min and death time 100.3 ± 2.4 min and 50 mg/ ml showed paralysis time 70.6 ± 2.1 min and death time 90.5 ± 3.7 min. The standard drug albendazole at 20 mg/ml concentration showed paralysis time 45.8 ± 2.4 min and death time 58.4 ± 2.8 min.

The phytochemical screening of ethanolic extract of stem bark of *Alangium salvifolium* was carried out by Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The phyto-compounds were analysed in the ethanolic extract of stem bark of *Alangium salvifolium* by GC-MS method and the results are presented in Table 2. The peaks of phytocompounds of the ethanolic extract of stem bark of *Alangium salvifolium* are depicted in Figure 1. The name of identified

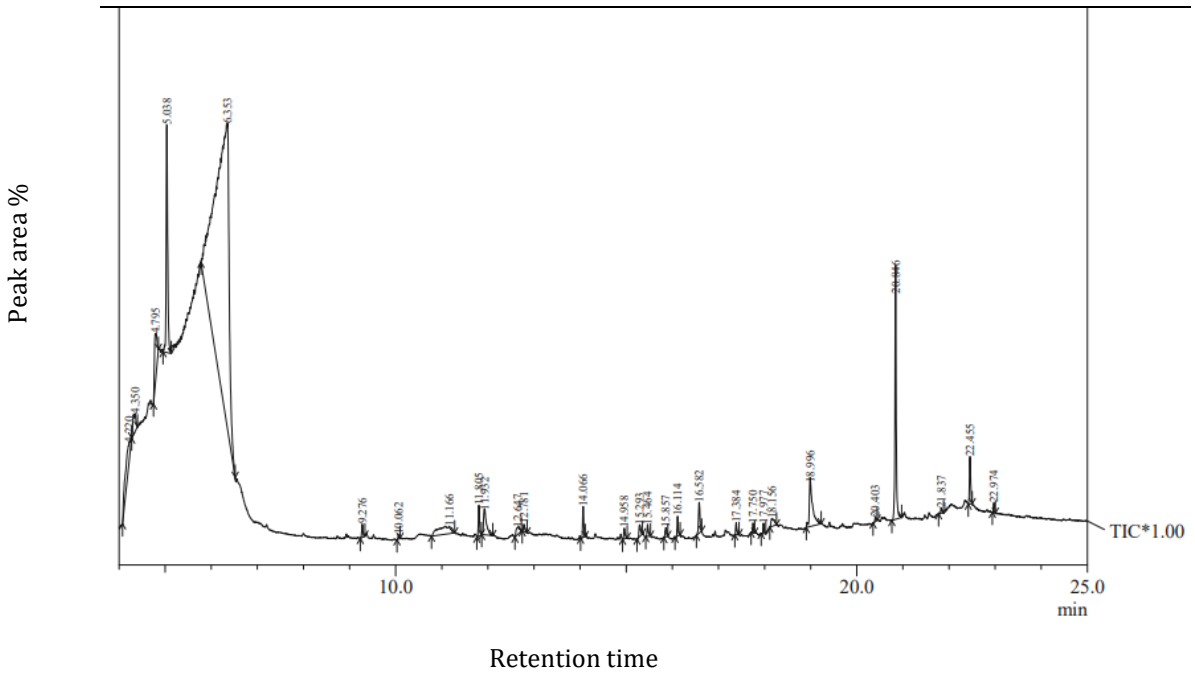

Fig. 1: GC-MS Chromatogram of ethanolic extract of stem bark of *Alangium salvifolium.*

phytocompounds with their Retention time (RT), Molecular formula (MF), Molecular weight (MW) and Peak area percentage are presented in Table 2. The GC-MS analysis of the ethanolic extract of stem bark of *Alangiums alvifolium* revealed the presence of twenty-nine phytocompounds and the identified compounds are 4-Decene, 2,2-dimethyl-, (e)- (2.52%); 3,6,9-Trioxadecanoic acid, TBDMS derivative (0.99%); 1-[(Trimethylsilyl) oxy]propan-2-ol (2.12%); 1,1,3-Triethoxybutane (5.98%); Glycerin (69.91%); 1-Tridecene (0.28%); Cyclohexane, octyl- (0.07%); Propionic acid, 3-iodo-, octadecyl ester (1.76%); 1-Pentadecene (0.64%); Diethyl phthalate (1.33%); Cyclodecane, octyl- (0.43%); 8-Pentadecanone (0.21%); 1-Heptadecene (0.57%); 8-Octadecanone (0.27%); Acetamide, 2-(diethylamino)-n-(2,6-dimethyl (0.37%);

Hexadecanoic acid, methyl ester (0.29%); Dibutyl phthalate (0.27%); 1-Heneicosanol (0.35%); Palmitic acid, TMS derivative (0.82%); Methyl stearate (0.24%); ethyl oleate (0.18%); 1-Nonadecene (0.18%); Oleic acid, (Z)-, TMS derivative (0.45%); 9,10-Dimethoxy-1,2,3,4-Tetrahydro-1,4-ethan (2.72%); Glycidyl oleate (0.08%); 1,2-Benzene dicarboxylic acid (5.59%); Octocrylene (0.11%); 1,4-Benzene dicarboxylic acid Bis(2-ethylhexyl) ester (1.07%) and Squalene (0.21%).

Discussion

Plants are rich sources for vital compounds in medicine, flavors, and fragrances, especially in India, with herbal remedies using complex plant extracts. Because these extracts contain varied phytochemicals, Gas Chromatography-Mass Spectrometry (GC-MS) serves as an excellent tool to identify and analyze these active ingredients for uses in cosmetics, drugs, and food.

The anthelmintic activity observed *in vitro* for the ethanolic extract derived from the stem bark of *Alangium salvifolium* is likely attributable to the presence of flavonoids and phenolic compounds. Phenolic compounds cause parasite death by uncoupling oxidative phosphorylation, a process that interferes with energy generation and the

Table 2: List of identified phytocompounds of ethanolic extract of *Alangium salvifolium* by GC-MS analysis

RT	Name	MW	MF	Peak Area%	Nature of compound	Activity*
4.220	4-Decene,2,2-dimethyl-, (e)-	168	$C_{12}H_{24}$	2.52	NF	NF
4.350	3,6,9-Trioxadecanoicacid, TBDMS derivative	292	$C_{13}H_{28}O_5Si$	0.99	Long chain carboxylic acid	NF
4.795	1-[(Trimethylsilyl)oxy] propan-2-ol	148	$C_6H_{16}O_2Si$	2.12	NF	NF
5.038	1,1,3-Triethoxybutane	190	$C_{10}H_{22}O_3$	5.98	Alkane	NF
6.353	Glycerin	92	$C_3H_8O_3$	69.91	Lipid	Bactericidal
9.276	1-Tridecene	182	$C_{13}H_{26}$	0.28	Acyclic olefin	Antibacterial
10.062	Cyclohexane, octyl-	196	$C_{14}H_{28}$	0.07	NF	NF
11.166	Propionic acid,3-iodo-, octadecylester	452	$C_{21}H_{411}O_2$	1.76	NF	NF
11.805	1-Pentadecene	210	$C_{15}H_{30}$	0.64	Alkene	Antimicrobial
11.932	Diethyl phthalate	222	$C_{12}H_{14}O_4$	1.33	Phthalate ester	Antimicrobial
12.647	Cyclo decane, octyl-	252	$C_{18}H_{36}$	0.43		
12.781	8-Pentadecanone	226	$C_{15}H_{30}O$	0.21	Ketone	Anticancer
14.066	1-Heptadecene	238	$C_{17}H_{34}$	0.57	Alkene	Antifungal
14.958	8-Octadecanone	268	$C_{18}H_{36}O$	0.27	Saturated fatty acid	Antimicrobial
15.293	Acetamide,2-(diethylamino)-n-2,6-dimethyl	234	$C_{14}H_{22}N_2O$	0.37	NF	NF
15.464	Hexadecanoic acid,methyl ester	270	$C_{17}H_{34}O_2$	0.29	NF	Antioxidant, Antimicrobial, Hemolytic, 5-Alpha reductase inhibitor, Cancer enzyme inhibitors in Pharmaceutical, Cosmetics, and Food industries
15.857	Dibutyl phthalate	278	$C_{16}H_{22}O_4$	0.27	Ester	Antibacterial
16.114	1-Heneicosanol	312	$C_{21}H_{44}O$	0.35	Long-chain primary fatty alcohol	Antimicrobial
16.582	Palmitic acid, TMS derivative	328	$C_{19}H_{40}O_2Si$	0.82	Saturated fatty acid	Antitumour
17.384	Methyl stearate	298	$C_{19}H_{38}O_2$	0.24	Fatty acid	Antioxidant, Antifungal, Anthelmintic
17.750	Ethyl oleate	310	$C_{20}H_{38}O_2$	0.18	Long-chain fatty acid ethyl ester	Antioxidant, Antibacterial
17.977	1-Nonadecene	266	$C_{19}H_{38}$	0.18	Alkane	Antimicrobial, Antioxidant
18.156	Oleic acid,(Z)-,TMS derivative	354	$C_{21}H_{42}O_2Si$	0.45	*Fatty acid*	Antioxidant, Antibacterial, Antitumor
18.996	9,10-Dimethoxy-1,2,3,4-tetrahydro-1,4-ethan	268	$C_{18}H_{20}O_2$	2.72	NF	NF
20.403	Glycidyl oleate	338	$C_{21}H_{38}O_3$	0.08	Fatty acid carboxylic ester	NF
20.846	1,2-Benzenedicarboxylic acid	390	$C_{24}H_{38}O_4$	5.59	Carboxylic ester	Antioxidant, Antifouling, Antimicrobial, Cancer Enzyme inhibitors in pharmaceutical, Cosmetics, Food industries
21.837	Octocrylene	361	$C_{24}H_{27}NO_2$	0.11	Long-chain *alkene*	Synthetic UV absorber
22.455	1,4-Benzenedicarboxylicacid, bis(2-ethylhexyl) ester	390	$C_{24}H_{38}O_4$	1.07	NF	NF
22.974	Squalene	410	$C_{30}H_{50}$	0.21	Terpenoids	Anticandidal activity, Antioxidant, Anti-inflammatory, Anticancer, Antioxidant, Anthelmintic

RT- Retention time; MF- Molecular formula; MW- Molecular weight; TBDMS-Tert-Butyl dimethylsilyl chloride, TMS-Trimethyl saline; *Biological activity of compounds based on Dr. Duke's phytochemicals and ethnobotanical databases.

glycoproteins on the cell surface (Manoj *et al.*, 2011). Tannins act as anthelmintics by binding to either free proteins within the host animal's gastrointestinal tract or to the protective glycoprotein cuticle of parasites, which can ultimately lead to the parasite's death (Mute *et al.*, 2009). Similarly, the *in vitro* anthelmintic activity of leaves of *Gymnema sylvestre* was reported (Narayanan *et al.*, 2020). The present study showed *in vitro* anthelmintic activity of ethanolic extracts of stem bark of *Alangium salvifolium*.

The GC-MS analysis of an ethanolic extract from the plant *Alangium salvifolium* identified a complex array of natural compounds that contribute to its potential therapeutic value. The most abundant of these compounds was glycerin, making up nearly 70% of the extract. Known for its properties as a lipid and a bactericide, glycerin is likely a major contributor to the extract's significant antimicrobial activity. (Nalawade *et al*., 2015). In addition, hydrocarbons such as 4-Decene, 2,2-dimethyl-, (e)- (2.52%); 1-Tridecene (0.28%); 1-Pentadecene (0.64%); 1-Heptadecene (0.57%) and 1-Nonadecene (0.18%) were identified. These compounds are generally classified as alkenes or acyclic olefins and have been associated with antibacterial, antifungal, and antimicrobial activities, thereby supporting their pharmacological relevance (Kumar *et al.*, 2011; Gomathi *et al*., 2019; Dukic *et al*., 2021).

Several esters and fatty acid derivatives were also present and contributing to the extract's bioactivity. Hexadecanoic acid, methyl ester (0.29%) is known for its antioxidant, anti-microbial, and cancer enzyme inhibitory properties, with applications in pharmaceuticals and food industries (Patil and Jadhav, 2021). Similarly, methyl stearate (0.24%) and Ethyl oleate (0.18%) exhibited antioxidant, antifungal, and antibacterial effects, strengthening their potential role as therapeutic molecules (Pinto *et al.*, 2017; Saravanakumar *et al.*, 2018). Palmitic acid, TMS derivative (0.82%) demonstrated antitumor activity, further emphasizing the potential of fatty acid derivatives in cancer therapy (Harada *et al.*, 2002). Oleic acid, (Z)-, TMS derivative (0.45%) was also identified, exhibiting strong antioxidant, antibacterial, and antitumor properties, aligning with reports on its protective role against oxidative stress and tumor progression (Carrillo Perez *et al*., 2012; Wei *et al.*, 2016).

Phthalates and related esters were another important group detected in the present study. Diethyl phthalate (1.33%) and Dibutyl phthalate (0.27%) exhibited antimicrobial activity, which supports their contribution to the overall pharmacological profile (Khatiwora *et al*., 2012; Premjanu and Jaynthy, 2014). Additionally, 1,2-Benzene dicarboxylic acid (5.59%) and 1,4-Benzenedicarboxylic acid,bis(2-ethylhexyl) ester (1.07%) demonstrated antioxidant, antimicrobial, and antifouling activities, making them highly valuable for industrial and pharmaceutical applications (El-Fayoumy *et al*., 2021).

Other significant compounds include 8-Pentadecanone (0.21%) with reported anticancer activity, and 8-Octadecanone (0.27%) which possesses antimicrobial properties, demonstrating the bioactivity of ketone-based compounds (Yoon *et al.*, 2011; Gomathi *et al.*, 2019). 1-Heneicosanol (0.35%), a long-chain fatty alcohol, exhibited antimicrobial activity, corroborating earlier studies on its pharmacological role (Arancibia *et al*., 2016). Furthermore, squalene (0.21%), a triterpenoid, is of particular importance due to its anticandidal, antioxidant, anti-inflammatory, and anticancer activities, consistent with its known application in nutraceuticals and cosmetics (Huang *et al*., 2009; Zore *et al*., 2011).

Other minor compounds such as Glycidyl oleate (0.08%); Octocrylene (0.11%); Propionic acid, 3-iodo-, octadecyl ester (1.76%) and Cyclodecane, octyl- (0.43%) were also present in the ethanolic extract from the plant *Alangium salvifolium*. Octocrylene is widely used as a synthetic UV absorber in cosmetic formulations (Suleiman *et al*., 2019). Although some compounds such as Acetamide, 2-(diethylamino)-n-(2,6-dimethyl (0.37%), and Cyclohexane, octyl-

(0.07%) have not been reported with significant biological activities, their occurrence contributes to the overall chemical diversity of the extract. The combination of these compounds suggests a synergistic contribution to the therapeutic potential of *Alangium salvifolium*.

Conclusion

The extract of *Alangium salvifolium* displays a wide range of biological activities including antimicrobial, antioxidant, anticancer, antifungal, anthelmintic and anti-inflammatory properties, validating its ethnomedicinal uses. The present findings highlight the pharmacological importance of fatty acids, esters, terpenoids, and hydrocarbons in contributing to plant bioactivity. The synergistic interactions of these phytocompounds may enhance the efficacy of the extract, providing a scientific basis for its traditional use in medicine and underscoring its potential for further drug discovery and industrial applications.

Ethical Statement

The authors confirm that all ethical issues have been dealt with the research ethics guidelines provided by the Post Graduate and Research Department of Biochemistry, Government Arts College, Kumbakonam, Tamil Nadu, India.

Author Contributions

Each author has contributed equally to the study's planning, analysis, writing, and editing. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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