



(REVIEW ARTICLE)



ACANTHUS ILICIFOLIUS L: ETHNOBOTANY, PHYTOCHEMISTRY, PHARMACOLOGY AND SYNTHESIS OF SILVER NANOPARTICLES (AGNPS)

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ABSTRACT

Acanthus ilicifolius belongs to the family *Acanthaceae* is a medicinal plant widely distributed in the coastal areas of tropical and subtropical regions. It has been traditionally used in various systems of folk medicine for managing conditions such as wounds, fever, inflammation, and respiratory problems. Phytochemical investigations have revealed the presence of several biologically active constituents, including flavonoids, alkaloids, phenolic compounds, and terpenoids. These constituents are associated with a range of biological effects, particularly antioxidant, anti-inflammatory, and immunomodulatory activities. Experimental pharmacological studies have further reported promising therapeutic potential of *A. ilicifolius*, including anticancer, neuroprotective, cardioprotective, immune-modulating, and wound-healing effects. Despite these encouraging findings, evidence from human clinical studies remains limited, and its therapeutic benefits and safety in humans have not yet been adequately established. Available toxicological studies suggest that the plant may be well tolerated at appropriate doses; however, excessive or prolonged administration should be approached with caution. Animal studies have indicated that higher doses of certain extracts may adversely affect hepatic and renal functions, emphasizing the importance of dose optimization and appropriate treatment duration. Further investigations are therefore required to clarify the pharmacological mechanisms, bioavailability, effective dosage, clinical efficacy, and long-term safety of *A. ilicifolius*. This review summarizes and critically discusses the traditional applications, phytochemical composition, pharmacological properties, and available toxicity data of *A. ilicifolius*, providing useful insights for researchers, healthcare professionals, and practitioners working in herbal and natural-product medicine.

Keywords: *Acanthus ilicifolius*, Phytochemistry, Pharmacology, Toxicity, Therapeutic potential.

1 INTRODUCTION

Acanthus ilicifolius is a perpetual herbaceous plant, prevalently perceived as “Holy leaved acanthus”. The plant regularly lives in regions of unobtrusive saltiness, shaping shrub around mangrove palms. For the most part, the plant is used in

standard systems of medicine, including traditional Indian remedy or *Ayurveda* and standard Chinese medication for treating various sicknesses [1, 2, 159]. Various parts of the plant have been used as unpleasant medicine for treatment of asthma, diabetes the composing revealed that the plant is well off in bioactive compounds [3, 4, 159]. This medicinal plant is commonly called with different names, English- Holy Mangrove Bengali - Harkuchkanta, Kentki Hindi- Hargoza Kannada- Mulluchulli Sanskrit- Harikusa Tamil- Kaludaimulli Telugu- Alasyakampa.

Acanthus ilicifolius (*Acanthaceae*) has received considerable attention due to its wide range of secondary metabolites and its traditional usage in Indian and Chinese system of medicine. This plant is reported to be a mangrove. Mangrove survives in the most hostile environment with fluctuating tidal and saline regime. Hence, these plants are considered to be rich sources of steroids, triterpenoids, saponins, flavonoids, alkaloids, and tannins [1, 2, 159].

Acanthus ilicifolius L. is a medicinal mangrove plant belonging to the family *Acanthaceae*. It is a perennial, spiny shrub or herb commonly found in mangrove forests, coastal wetlands, estuaries, and tidal areas of tropical and subtropical regions [140-142, 159]. *A. ilicifolius* is regular in estuaries all through Asian tropics from India to Polynesia and northern Australia [1-20-35-40]. Asia and Australia have the best assortment and conveyance of mangrove species known to mankind. In India, it is found ordinarily in the east and west drifts, likewise in Meghalaya and the Andaman. It is a genuine mangrove animal group found in the most foreshore area [1-23-35-50]. It typically develops on waterway banks or tidal channel sides or low swampy zones in mangrove woodlands and regions [1-50, 159].

Table1: Biological source

Parameter	Description
Biological source	<i>Acanthus ilicifolius</i> L.
Family	<i>Acanthaceae</i>
Genus	<i>Acanthus</i>
Species	<i>Acanthus ilicifolius</i>
Common names	Sea holly, Holly-leaved acanthus, Sea holly mangrove
Habit	Perennial spiny shrub/herb
Distribution	Coastal and mangrove regions of India and Southeast Asia
Medicinal parts	Leaves, roots, stems, bark and whole plant
Major phytoconstituents reported	Flavonoids, phenolic compounds, alkaloids, terpenoids, lignans and other secondary metabolites

2 ACANTHUS ILICIFOLIUS : BOTANY

Morphology *Acanthus ilicifolius* (Figure-1) is a perennial herb typically growing in coastal areas, including tidal flats, mangroves, and salt marshes [6-14]. It has a unique morphology that sets it apart from other plants. Kingdom: Plantae Order: Lamiales Family: *Acanthaceae* Genus: *Acanthus* Species: *A. ilicifolius*. *Acanthus ilicifolius* is a perennial, herbaceous plant that belongs to the family *Acanthaceae* [1-50]. It typically grows in coastal regions and mangrove habitats. The plant has the following morphological characteristics [7-11, 159].

Leaves: The leaves of *Acanthus ilicifolius* are large, leathery, and glossy. They are arranged alternately along the stem and are deeply lobed with spiny margins. The leaf blades are elliptical to lanceolate in shape and can grow up to 15 cm in length [1-10-34].

Stem: The stem of *Acanthus ilicifolius* is erect and can grow up to 1.5 m in height. It is usually green to brown and has a slightly woody texture at the base [1-11-13-57].

Flowers: *Acanthus ilicifolius* are arranged in dense spikes, which arise from the axils of the leaves. The spikes can be up to 15 cm long and contain numerous flowers. The flowers are tubular and have a white to pale pink color. They are bilabiate, with a larger upper lip and a smaller lower lip, and have two stamens and a single pistil [1-10].

Fruits: The fruits of *Acanthus ilicifolius* are small, capsule-like structures that contain numerous seeds. The capsules are oblong and have a brownish color when mature. They split open to release the seeds, which are small, brown and flattened [1-10-48].

Roots: *Acanthus ilicifolius* has a fibrous root system that spreads horizontally in the substrate, allowing the plant to anchor itself in its coastal habitat's muddy and saline soils [1-10]. However, the morphology of *Acanthus ilicifolius* is characterized by large, glossy leaves with spiny margins, erect stems, dense spikes of tubular flowers, capsulelike fruits, and a fibrous root system [1-15-16]. These morphological features enable *Acanthus ilicifolius* to adapt and thrive in its coastal habitat [1-15-17].



Figure1: *Acanthus ilicifolius*

3 ACANTHUS ILICIFOLIUS: DISTRIBUTION

Acanthus ilicifolius has a wide distribution in coastal regions of tropical and subtropical countries. It is commonly found in India, Malaysia, Thailand, Indonesia, and Australia [1-18-20]. In India, it is found along the coastal areas of the Bay of Bengal and the Arabian Sea, including the Sundarbans mangrove forest [1-6,21-57]. It is found in mangrove forests and mudflats in Malaysia, particularly in Johor, Perak, and Selangor [1-8-16]. In Thailand, *Acanthus ilicifolius* is commonly found in coastal areas, including the Andaman Sea and the Gulf of Thailand [21]. In Indonesia, it is distributed along the coastlines of Sumatra, Java, Bali, and Kalimantan and is also found in the mangrove forests of Papua New Guinea and the Solomon Islands [22]. In Australia, *Acanthus ilicifolius* is found in the coastal areas of Queensland, New South Wales, and the Northern Territory [1-23-24].

4 ACANTHUS ILICIFOLIUS: ETHNOBOTANY

According to traditional medicine, particularly Chinese and Indian medicine, *A. ilicifolius* possesses potential therapeutic properties for addressing a range of health issues, including psoriasis, rheumatism, asthma, paralysis, stomach ailments, leukemia, diabetes, leprosy, dyspepsia, hepatitis, ringworm, and various skin conditions. Additionally, it has been cited for its efficacy in treating edema and inflammation of the biliary system [1-43,44]. As recorded in traditional medicine, the whole plant decoction was mixed with sugar candy and cumin for indigestion treatment [1-45]. The root was often used to treat coughs and asthma due to its expectorant effects. The Indo-Chinese and Siamese used the roots in the treatment of damaged nerves, nervous disorders, body weakness, vaginal infection, paralysis, fluid retention, and skin disease [1-46]. The mucilaginous leaves were also applied as a medicinal compress for rheumatism and neuralgia in Goa [1-47]. Malay communities in Malaysia have utilized the plant parts of *A. ilicifolius* for a variety of therapeutic purposes. Specifically, the seeds have been employed as a natural remedy in managing cough and for deworming infants

[1-48, 49]. The roots have been applied to treat shingles and the leaf extracts have been applied to stimulate hair growth. The prickly leaves have been used in Malay rituals, where they are placed beneath houses to ward off disturbances by mystical creatures. The crushed fruit from the plant has served as a remedy for purifying the blood and as a dressing for burns. In cases of snakebites or arrow poisoning, a compress crafted from either the fruit or the roots was applied to the affected area [1-50]. In Thailand, extracts from the bark of the plant have been employed to treat dermatitis and allergies [1-44]. Additionally, a mixture of the plant's aerial parts and ginger has been documented as an effective remedy for alleviating constipation and soothing sore legs. The whole plant also can be used in rice sacks as a drying agent [1-51]. Moreover, a decoction made from the leaves can be ingested to aid in the birthing process. A combination of the leaves and either the stems or roots can be consumed to promote longevity and improve the health of one's hair [1-24-46]. Table 1 summarizes the uses of *A. ilicifolius* in ethnobotany [1-52].

Table 2: Ethnobotany studies of *A. ilicifolius*

S. No.	Plant Part Used	Traditional Uses / Ailments	Country / Region	Reference
1	Fruit and seeds	Asthma, acne, breast cancer, fistula, gastritis, and sinusitis	Indonesia	[53]
2	Roots	Snake bite, skin allergies, diabetes, rheumatoid disorders, and edema	India	[54]
3	Roots	Snake bite, skin allergies, diabetes, rheumatoid disorders, and edema	Vietnam	[55]
4	Leaves	Rheumatism, neuralgia, cancer, fever, toothache, and swelling	Goa	[56]
5	Leaves	Rheumatism, neuralgia, cancer, fever, toothache, and swelling	Bangladesh	[57]
6	Leaves	Rheumatism, neuralgia, cancer, fever, toothache, and swelling	India	[58]
7	Whole plant	Kidney stones, cough, and hepatitis	China	[55]
8	Tender shoots, fruits, and roots	Snake bite	Malaysia	[59]
9	Bark	Cold and antiseptic applications	Thailand	[60]

5 ACANTHUS ILICIFOLIUS: PHARMACOLOGY

Acanthus ilicifolius has been used in traditional systems of medicine, such as *Ayurveda* in India and Traditional Chinese Medicine, for centuries. In *Ayurveda*, the plant is known as "Makoy" and has been used for its hepatoprotective, anti-inflammatory, and anti-diabetic properties [1-24-27]. In Traditional Chinese Medicine, *Acanthus ilicifolius* is known as "Shan Ci Gu" and has been used for its diuretic, anti-inflammatory, and antipyretic properties (Wu et al., 2011). The traditional use of *Acanthus ilicifolius* in these systems of medicine highlights its significance as a medicinal plant with a long history of use [1-28].

Besides its ornamental value, *Acanthus ilicifolius* has a long history of traditional medicinal use and has been studied for its potential pharmacological properties, making it a subject of interest in ethnobotany and natural product research [1-29]. *A. ilicifolius* is popularly recognized for its full scope of secondary metabolites and its traditional usage in Indian and Chinese systems of medicine. Folklore claims for this plant are as aphrodisiac blood purifier, diuretic, for treatment of asthma, diabetes, dyspepsia, hepatitis, leprosy, neuralgia, paralysis ringworm, rheumatism, skin diseases, snakebite, stomach pains, leucorrhoea, leukemia [1-30, 31]. The plant is used to prepare the *Ayurvedic* medicine known as Sahachara which is used for rheumatic complaints. In Thai traditional medicine, the plant is utilized as a purgative and as an anti-inflammatory; the leaves are dispensed with pepper (*Piper nigrum* L.) as tonic pills for longevity (aphrodisiac). It is also employed as an emollient fomentation for rheumatism and neuralgia. It is widely believed among mangrove dwellers that chewing the leaves will protect against snake bite [1-32, 159]. Tea brewed from the leaves relieves pain and purifies blood [1-94]. The root boiled in milk is largely used in leucorrhoea and general debility [1-33, 159]. A decoction of the plant with sugar candy and cumin is used in dyspepsia with acid eructations. Leaves are bruised and soaked in water for external application and are also used as an expectorant. It is also considered to be a diuretic and it is used as a remedy for dropsy and bilious swellings [34, 159].

Acanthus ilicifolius has also been used traditionally by indigenous cultures in different regions where it is found. For example, in the Sundarbans mangrove forest in India and Bangladesh, local communities have used the plant for various medicinal purposes. The leaves and stems of *Acanthus ilicifolius* are used as poultices for treating skin infections, wounds, and insect bites, and the plant is also used as a remedy for coughs, colds, and fevers [35]. On the other hand, it has a long history of traditional medicinal use by local communities in the regions where it is found. In traditional systems of medicine, different parts of the plant, including the leaves, stems, and roots, are used for various medicinal purposes. These traditional uses of *Acanthus ilicifolius* by indigenous cultures highlight the plant's cultural significance and its deep-rooted history of medicinal use.

In India, *Acanthus ilicifolius* has been used in traditional *Ayurvedic* medicine for treating a wide range of ailments. The leaves and roots of the plant are used as a poultice to treat wounds, cuts, and skin infections due to their reported anti-microbial properties [36]. The plant is also diuretic, antipyretic, and analgesic and is believed to have anti-inflammatory and anti-arthritis properties [36-37]. In addition, the leaves of *Acanthus ilicifolius* are used in the treatment of diabetes and liver disorders and are also believed to have anti-cancer properties [38].

In Malaysia, *Acanthus ilicifolius* has been used traditionally for treating various conditions, including fever, cough, cold, and wounds [39]. The leaves of the plant are used as poultices for treating skin infections, and the roots are used for treating digestive disorders and as a diuretic [35]. The plant is also believed to have anti-inflammatory properties and is used for treating inflammation-related ailments such as arthritis [39-40].

In Thailand, *Acanthus ilicifolius* has been used traditionally for treating snakebites, wounds, and skin infections [39]. The plant is also an antidote for poisoning and a remedy for fever and cough [40]. In Indonesia, *Acanthus ilicifolius* is used traditionally for treating various conditions, including fever, cough, cold, and skin infections [41]. The plant is also used as a poultice for treating wounds and as a diuretic [42]. Apart from its traditional uses, *Acanthus ilicifolius* has also been the subject of scientific research to explore its potential pharmacological properties. Numerous studies have investigated the chemical constituents and biological activities of *Acanthus ilicifolius*, revealing its potential as a source of bioactive compounds with various medicinal properties [40].

The anti-microbial activity of alcoholic, butanolic, and chloroform extracts of leaves and roots of the plant *A. ilicifolius* were studied [159]. Ampicillin and clotrimazole were used as standard anti-bacterial and anti-fungal agents, respectively. The result of the study revealed that the alcoholic and chloroform extract of the leaves exhibited strong inhibitory action against *Bacillus subtilis*, *Staphylococcus aureus*, *Candida albicans*, *Aspergillus fumigatus*, and *Aspergillus niger* and moderate inhibitory action against *Pseudomonas aeruginosa* and *Proteus vulgaris* [159].

6 ACANTHUS ILICIFOLIUS: PHYTOCHEMISTRY

Phytochemical investigation of *A. ilicifolius* indicated the presence of alkaloids, glycosides, triterpenoids, saponins, flavonoids, steroids, fatty acid derivatives and. List of Phytochemicals are shown in Table 2 [61].

Table 3: Chemical compounds of *Acanthus ilicifolius*.

S. No.	Plant Part	Extract/Solvent	Phytochemical Constituents / Chemical Classes
1	Root	Ethanollic / Methanollic / Chloroform / Hexane	Alkaloids, glycosides, lignans, triterpenoid saponins, sterols, fatty acids, coumaric acid derivatives
2	Leaves	Ethanollic / Methanollic / Chloroform / Hexane	Alkaloids, glycosides, lignans, triterpenoid saponins, sterols, fatty acids, coumaric acid derivatives
3	Aerial parts	Ethanollic / Methanollic / Chloroform / Hexane	Alkaloids, glycosides, lignans, triterpenoid saponins, sterols, fatty acids, coumaric acid derivatives
4	Stem	Ethanollic / Methanollic / Chloroform / Hexane	Alkaloids, glycosides, lignans, triterpenoid saponins, sterols, fatty acids, coumaric acid derivatives
5	Pods	Ethanollic / Methanollic / Chloroform / Hexane	Alkaloids, glycosides, lignans, triterpenoid saponins, sterols, fatty acids, coumaric acid derivatives

Table 4: Biological activities in *Acanthus ilicifolius*.

S. No.	Pharmacological Activity	Plant Part / Extract / Active Compound	Experimental Model / System	Major Findings / Observations	Ref.
1.1	Anti-inflammatory / Free Radical Scavenging Activity	Methanolic fraction of leaves	Rat paw edema; peritoneal inflammation model; LPS-stimulated PBMCs; in-vitro antioxidant assays	Significant inhibition of carrageenan-induced paw edema, protein exudation, and leukocyte migration. Inhibited COX-1, COX-2 and 5-LOX activities and reduced TNF- α and IL-6 production. Demonstrated significant DPPH, ABTS, superoxide and hydroxyl radical scavenging activity. Increased FRAP and TRAP levels, indicating enhancement of antioxidant status.	[62]
1.2	Antimicrobial Activity	Alcoholic, ethanol, methanol, aqueous, butanol and chloroform extracts of leaves and roots	Agar cup-plate method; <i>Bacillus subtilis</i> , <i>Staphylococcus aureus</i> , <i>Pseudomonas aeruginosa</i> , <i>Proteus vulgaris</i> , <i>Candida albicans</i> , <i>Aspergillus fumigatus</i> and <i>A. niger</i>	Alcoholic and chloroform extracts showed strong activity against <i>B. subtilis</i> , <i>S. aureus</i> , <i>C. albicans</i> , <i>A. fumigatus</i> and <i>A. niger</i> . Moderate activity was observed against <i>P. aeruginosa</i> and <i>P. vulgaris</i> . Ethanol extract showed greater antimicrobial activity than methanol and aqueous extracts.	[63–65]
1.3	Anti-diabetic Activity	Ethanollic root extract	Alloxan-induced diabetic rats	Oral administration of 200 and 400 mg/kg extract significantly reduced blood glucose levels in acute and repeated-dose studies. Histopathological examination indicated regeneration/recovery of pancreatic β -cells, with better recovery at 400 mg/kg.	[66]
1.4	Anti-osteoporotic Activity	Acteoside, isoacteoside and (+)-lyoniresinol 3 α -O- β -glucopyranoside from leaves	MC3T3-E1 osteoblast cells	The isolated compounds produced moderate stimulatory effects on osteoblast growth and bone-forming activity. Acteoside enhanced alkaline phosphatase (ALP) activity, suggesting an estrogen receptor-associated mechanism.	[67–69]
1.5	Anticarcinogenic / Tumour Reducing Activity	Alcoholic extract	Tumour-bearing mice; DMBA/croton-oil-induced skin papilloma model; cancer cell studies	Extract showed cytotoxicity after 72 h and significantly increased the lifespan of ascites tumour-bearing mice. It reduced solid tumour development and delayed	[70–77]

				the onset of chemically induced skin papillomas. Activity was associated with antioxidant and possible apoptosis/neovascularization-related mechanisms.	
1.6	Antioxidant and Cytotoxic Activity	Methanolic and ethanolic extracts, particularly flower and leaf extracts	DPPH/antioxidant assays; L-929, HeLa and other cancer cell lines	Methanol extract contained phenolic and other antioxidant constituents and showed considerable free-radical-scavenging activity. Ethanolic leaf extract exhibited cytotoxicity toward L-929 cells, while methanolic extract showed cytotoxicity against HeLa and other cell lines. Activity may be related to flavonoids, phenolics, saponins and other secondary metabolites.	[78–93]
1.7	Anticarcinogenic / Anti-genotoxic Activity	<i>A. ilicifolius</i> extract	Hydrocortisone-induced genotoxicity model	Extract demonstrated protective/anti-genotoxic effects and was reported to effectively counter oxidative/free-radical-mediated damage.	[94]
1.8	Anti-leishmanial Activity	2-Benzoxazolinone (BOA) isolated from leaves	<i>Leishmania donovani</i>	BOA exhibited significant in-vitro anti-leishmanial activity with an LC ₅₀ of approximately 40 µg/mL, comparable with the reference drug pentamidine.	[95]
1.9	Anti-ulcer Activity	Methanolic leaf extract (MEAI)	Pylorus-ligation and ethanol-induced gastric ulcer models	Extract at tested doses significantly reduced gastric lesions, gastric volume, free acidity and ulcer index. Findings suggested anti-secretory, anti-ulcerogenic and ulcer-healing properties.	[96]
1.10	Osteoblastic Activity	Acancifoliuside, a coumaric acid derivative isolated from leaves	MC3T3-E1 osteoblast cells	Acancifoliuside significantly enhanced osteoblast growth and differentiation, indicating potential bone-forming and osteoporosis-preventive effects.	[97]
1.11	Hepatoprotective Activity	Alcoholic extract	CCl ₄ -induced hepatotoxicity in rats	Oral administration at 250 and 500 mg/kg significantly reduced CCl ₄ -induced hepatic damage, as indicated by improvements in serum and tissue biochemical markers. Effects were comparable with curcumin (100 mg/kg, p.o.).	[98]
1.12	Antinociceptive Activity	Aqueous, alcoholic and methanolic extracts;	Experimental animal models of inflammatory pain	Extracts demonstrated analgesic and anti-inflammatory effects. Alkaloid fractions	[99–102]

		alkaloids; BOA derivatives		significantly inhibited acetic-acid-induced inflammatory pain. BOA and related derivatives may contribute to the observed analgesic activity.	
1.1 3	Antiprotozoal Activity	2-Benzoxazolinone isolated from leaves	<i>Leishmania donovani</i>	2-Benzoxazolinone exhibited significant antileishmanicidal activity, supporting the potential antiprotozoal properties of <i>A. ilicifolius</i> .	[103 – 104]
1.1 4	Antiasthmatic Activity	Ethanollic root extract	Isolated guinea-pig tracheal-chain preparation; anaphylactic shock model	Extract relaxed histamine-induced contraction of tracheal tissue and partially protected against antigen-induced anaphylactic shock. It also demonstrated short-term, non-specific antispasmodic activity.	[105]
1.1 5	Hypocholesterolemic Activity	Stigmasterol and other phytosterol constituents	Mechanistic/pharmacological evidence related to cholesterol absorption	Stigmasterol, structurally similar to cholesterol, may compete with cholesterol for intestinal absorption, thereby potentially reducing plasma cholesterol levels.	[106 – 108]
1.1 6	Neuroprotective Activity	Plant extracts; flavonoid and terpenoid constituents	Experimental models of oxidative stress and neurotoxicity	Extracts have been reported to protect neuronal cells against oxidative and glutamate-induced damage by reducing oxidative stress, modulating inflammation and improving antioxidant defenses.	[109 – 110]
1.1 7	Cardioprotective Activity	Plant extracts; flavonoid and phenolic constituents	Oxidative stress, ischemia-reperfusion and doxorubicin-induced cardiac injury models	Extracts demonstrated protective effects against cardiac injury, potentially through reduction of oxidative stress, improvement of antioxidant enzyme levels and suppression of inflammatory responses.	[110 – 113]
1.1 8	Immunomodulatory Activity	<i>A. ilicifolius</i> extracts; alkaloids, flavonoids and phenolics	Experimental immune-response models	Reported to modulate immune responses by influencing macrophages, lymphocytes, NK cells, cytokines and immunoglobulins. These effects have been associated with bioactive alkaloid, flavonoid and phenolic constituents.	[114 – 116]
1.1 9	Wound Healing Activity	Plant extracts; flavonoid and terpenoid constituents	Experimental wound-healing models	Extracts have been reported to promote wound repair through fibroblast proliferation, collagen synthesis and angiogenesis	[115, 117–118]

				while reducing inflammation and oxidative stress. Further clinical studies are required to establish safety and efficacy in humans.	
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7 ACANTHUS ILICIFOLIUS: GREEN NANOPARTICLE SYNTHESIS

Synthesis of ecofriendly silver nanoparticles is of great importance in the field of nanotechnology. Nanotechnology is applied in every aspect of life—medicine, food, or the environment—and nanomaterials are available in different forms, such as powder, particles, clusters, tubes or films, and sizes [147-158]. At present, nanoparticles are extensively synthesized and utilized owing to their diverse and versatile applications. The presence of a large surface area with tunable size and properties makes them prospective candidates for a wide spectrum of applications such as drug delivery, pharmaceuticals, food packaging and biotechnology [147-158]. Various nanomaterials such as zinc oxide (ZnO), titanium dioxide (TiO₂), copper (Cu), silver (Ag) and gold (Au) grabbed the interest in recent years. Among all, AgNPs, due to their unique physicochemical properties and chemical inertness, find applications in various fields such as food additives, packaging and the biomedical field [147-158]. Traditionally, AgNPs offer good broad-spectrum antimicrobial properties over a wide range of microorganisms. Moreover, this inherent antimicrobial efficacy of AgNPs, even at low concentrations, was employed to design many biomedical products. Hence, many medicinal and anti-ageing formulations with AgNPs prove to be effective in minimizing side effects caused by the generation of free radicals. Also, studies on the incorporation of plant extracts such as aloe vera plant extract and boswellic acid in polymer blends have improved antimicrobial properties [147-158].

Acanthus ilicifolius L. (Family: *Acanthaceae*), commonly known as Sea Holly or Holly Mangrove, is a medicinal mangrove plant widely distributed in the coastal regions of India, Southeast Asia, and Australia. The plant is rich in secondary metabolites such as flavonoids, alkaloids, tannins, phenolics, glycosides, terpenoids, and saponins, making it an excellent candidate for the green synthesis of metal nanoparticles. These phytochemicals act as natural reducing, capping, and stabilizing agents during nanoparticle formation [119, 159]. Nanoliposomes have been referred to as nanoscale bilayer lipid vesicles since the term liposome is a definition, including various types of vesicles with average size up to several micrometers [143-159]. Micro-balloons also known as hollow microsphere are those system that tends to be one of the most suitable approach for gastric retention micro balloons drug delivery system can be explained as it is containing empty particles of spherical shape without core identically having a size than 200 micrometers [144].

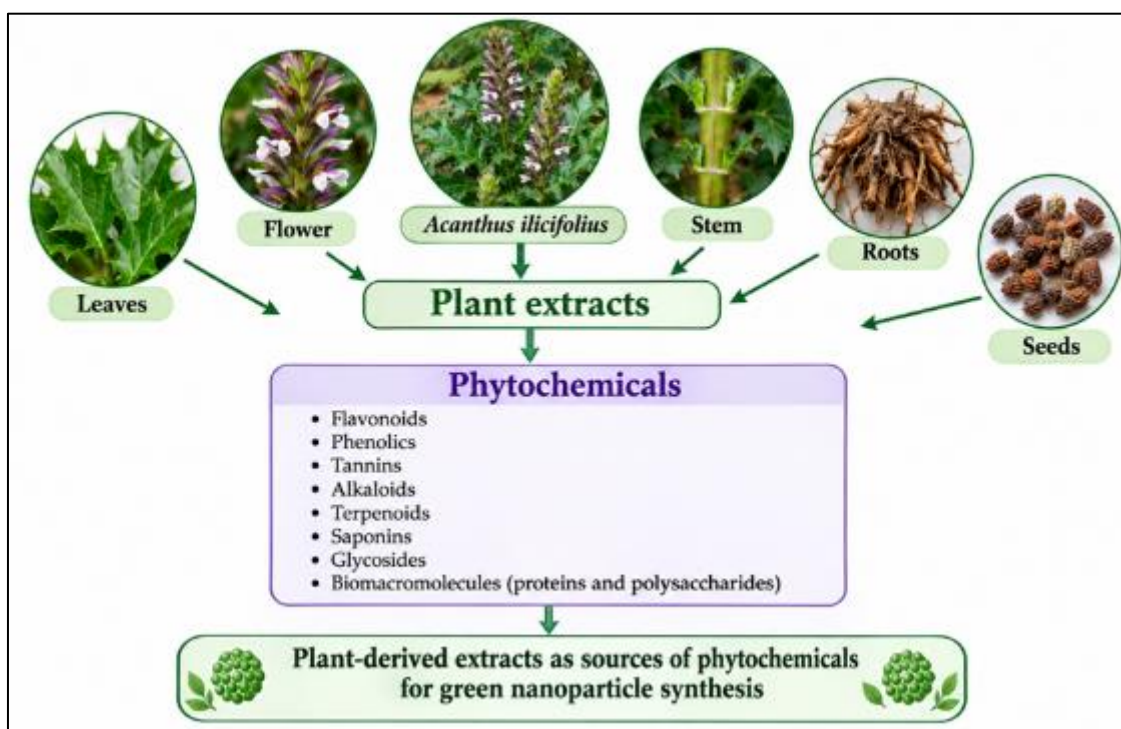


Figure 2: Plant-derived extracts as sources of phytochemicals for green nanoparticle synthesis

Nanoemulsions are thermodynamically or kinetically stable colloidal dispersions consisting of oil, water, surfactant, and co-surfactant, with droplet sizes generally ranging from 20 to 200 nm. Due to their extremely small droplet size and

large interfacial surface area, nanoemulsions provide excellent solubilization and delivery of poorly water-soluble drugs [160].

Table 5: Major Phytochemicals Present in *Acanthus ilicifolius* and Their Role in Green Nanoparticle Synthesis:

Phytochemical Class	Examples Reported in <i>Acanthus ilicifolius</i>	Role in Green Nanoparticle Synthesis	References
Flavonoids	Quercetin, Kaempferol derivatives, Apigenin derivatives	• Donate electrons for reduction of $\text{Ag}^+/\text{Au}^{3+}$ ions • Act as capping and stabilizing agents • Prevent nanoparticle aggregation • Improve colloidal stability	120
Phenolic Compounds	Gallic acid derivatives, Phenolic acids, Hydroxybenzoic acid derivatives	• Strong reducing agents • Facilitate rapid nucleation of nanoparticles • Enhance antioxidant activity of synthesized nanoparticles	120
Tannins	Hydrolysable and condensed tannins	• Chelate metal ions • Stabilize nanoparticle surfaces • Prevent particle agglomeration • Improve long-term stability	123
Alkaloids	2-Benzoxazolinone, Acanthifoline, Trigonelline	• Participate in metal ion reduction • Bind nanoparticle surfaces through nitrogen-containing groups • Enhance antimicrobial activity of nanoparticles	120
Terpenoids	Triterpenoids, Steroidal compounds	• Reduce metal ions • Enhance nanoparticle biocompatibility • Contribute antioxidant and anti-inflammatory properties	120
Saponins	Triterpenoid saponins	• Act as natural surfactants • Prevent aggregation of nanoparticles • Improve nanoparticle dispersion and stability	123
Glycosides	Ilicifolioside A, Ilicifolioside B, Ilicifolioside C	• Surface coating and stabilization • Control nanoparticle growth • Enhance aqueous dispersion and shelf-life	124
Polysaccharides	Plant mucilage and polysaccharide fractions	• Act as capping agents • Provide steric stabilization • Prevent agglomeration • Improve nanoparticle dispersibility	121

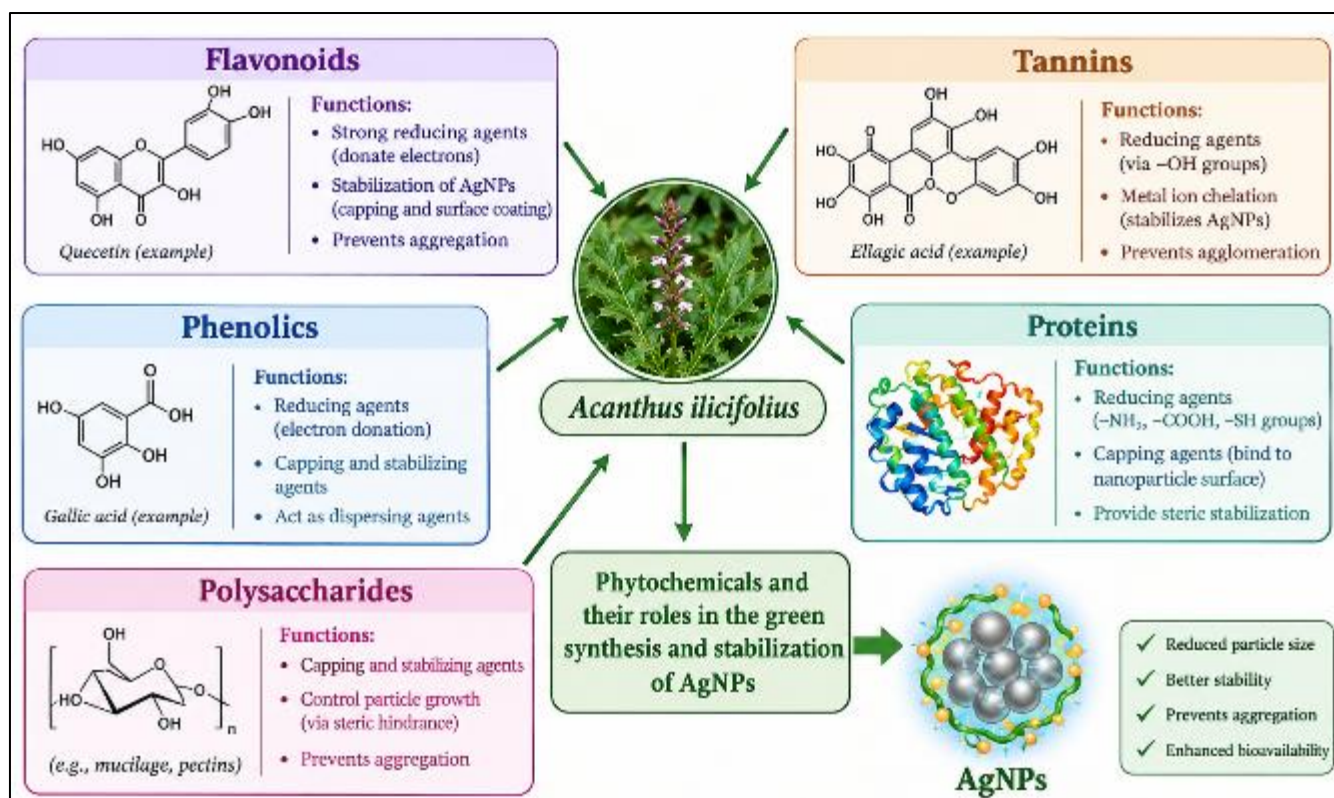


Figure 3: Phytochemicals and their roles in the green synthesis and stabilisation of AgNPs.

Table 6: Plant-Mediated Green Synthesis of Silver Nanoparticles

Plant Part / Extract	Synthesis Conditions	Morphology	Particle Size	Characterization	Reported Biological Activities	References
Leaf Extract	5 mM AgNO ₃ ; Extract:AgNO ₃ ratio 1:2; pH 10; 60°C; 200 rpm; 6 h incubation	Predominantly spherical; non-aggregated particles	36–78 nm (SEM); average 86.86 nm (AFM)	UV-Vis (400 nm), FTIR, SEM, EDX, AFM	Antibacterial activity against <i>Vibrio parahaemolyticus</i> , <i>Pseudoalteromonas ostreae</i> , and <i>Shewanella khirikhana</i> ; inhibition zones up to 15 ± 0.8 mm	125
Leaf Extract (Earlier Study)	5 mM AgNO ₃ ; extract concentration 100 mg/mL; extract:AgNO ₃ ratio 1:10; 40°C; 150 rpm; 24 h	Spherical AgNPs	~50 nm	UV-Vis, FTIR, XRD, SEM, EDAX	Significant antimicrobial activity against pathogenic microorganisms	127
Pneumatophore Extract	0.1 M AgNO ₃ ; Extract:AgNO ₃ ratio 1:9; 80°C; 200 rpm; 90 min	Uniform spherical nanoparticles	~15 nm	UV-Vis (420 nm), FE-SEM, Cryo-TEM, AFM, DLS, Zeta Potential	Antibacterial, antioxidant, anti-biofilm, and anticancer activity against HepG2	126

					hepatocellular carcinoma cells	
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8 ACANTHUS ILICIFOLIUS: FACTORS CONTROLLING SYNTHESIS OF AGNPS

The green synthesis of silver nanoparticles (AgNPs) using *Acanthus ilicifolius* extract involves a series of interconnected steps including reduction, nucleation, growth, capping, and stabilization. The phytochemicals present in the plant extract, such as flavonoids, phenolics, tannins, alkaloids, terpenoids, glycosides, proteins, and polysaccharides, act simultaneously as reducing, capping, and stabilizing agents.

Table 7: Mechanism of AgNP Formation Using *Acanthus ilicifolius* Extract

Step	Mechanism	Role of <i>A. ilicifolius</i> Phytochemicals
1. Reduction of Ag ⁺ ions	Ag ⁺ ions from AgNO ₃ are reduced to metallic silver (Ag ⁰).	Phenolics, flavonoids, and terpenoids donate electrons through hydroxyl and carbonyl groups.
2. Nucleation	Reduced silver atoms aggregate to form nanoclusters.	Bioactive compounds regulate nucleation rate and particle formation.
3. Growth	Silver nuclei grow through deposition of Ag ⁰ atoms.	Phytochemicals control growth kinetics and morphology.
4. Capping	Biomolecules adsorb on nanoparticle surfaces.	Proteins, tannins, glycosides, and polysaccharides form a protective coating.
5. Stabilization	Prevention of aggregation and oxidation.	Surface-bound phytochemicals provide steric and electrostatic stabilization.

8.1 General Reaction

$$\text{AgNO}_3 \rightarrow \text{Ag}^+ + \text{NO}_3^-$$

$$\text{Ag}^+ + \text{Phytochemicals} \rightarrow \text{Ag}^0 + \text{Phytochemicals}^+$$

$$\text{Ag}^0 \rightarrow \text{AgNPs}$$

$$\text{AgNPs} + \text{Phytochemicals} \rightarrow \text{Stabilized AgNPs}$$

The FTIR analysis of *A. ilicifolius*-mediated AgNPs has revealed the presence of hydroxyl, carbonyl, alkane, alkene, and amine functional groups that participate in the reduction and stabilization process [128].

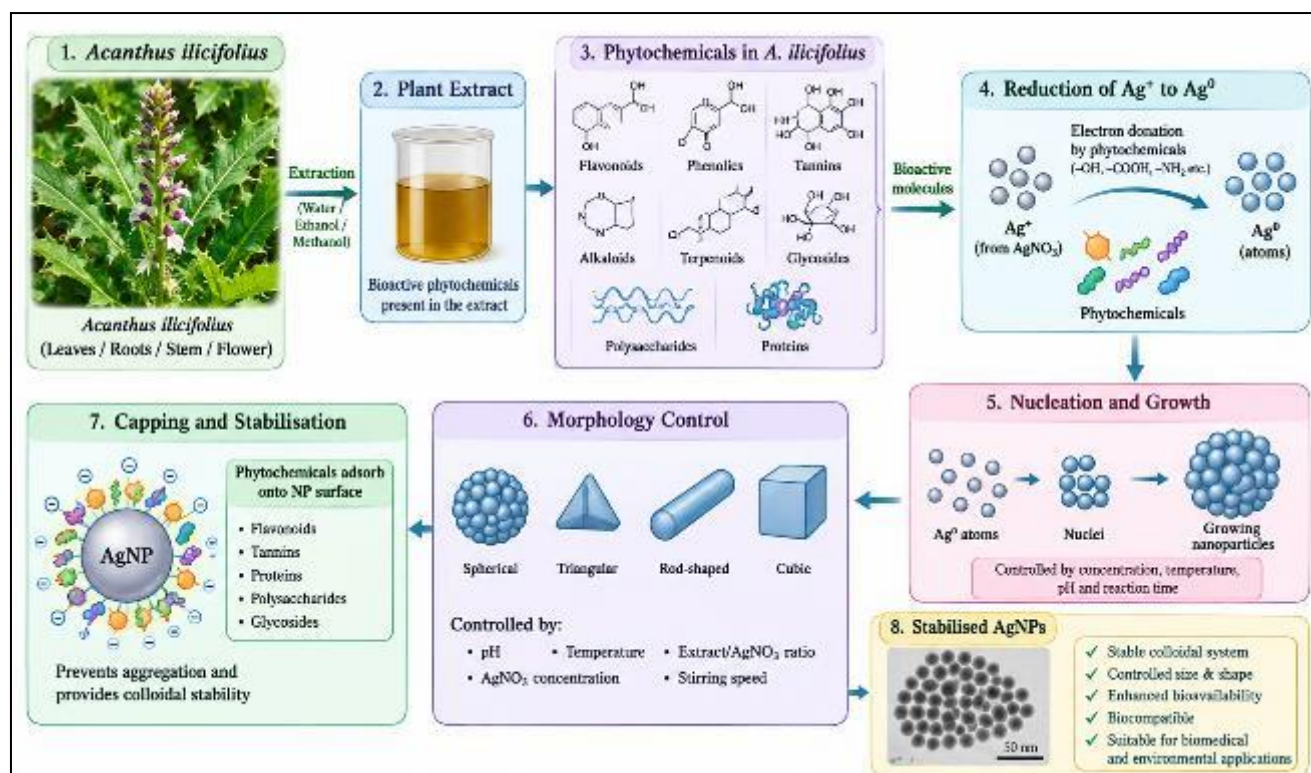


Figure 4: Mechanistic pathway of phytochemical-mediated synthesis, morphology control, and stabilisation of AgNPs using *Acanthus ilicifolius* [129-132].

Table 8: Factors Influencing AgNP Formation from *Acanthus ilicifolius* Extract

Factor	Effect on Nanoparticles	Optimum/Reported Range
pH	Influences ionization of phenolics and reduction rate; alkaline pH generally produces smaller particles.	pH 8–10
Temperature	Accelerates reduction and nucleation; excessive temperature may degrade phytochemicals.	40–80°C
Reaction Time	Controls completion of reduction and particle growth.	30 min–24 h
AgNO_3 Concentration	Determines availability of silver ions and particle yield.	1–5 mM
Extract Concentration	Provides reducing and stabilizing biomolecules.	Species-dependent
Extract-to- AgNO_3 Ratio	Controls nucleation and particle size distribution.	1:2 to 1:10
Stirring Speed	Improves homogeneity and mass transfer.	150–250 rpm
Storage Conditions	Affect long-term colloidal stability.	4°C, dark conditions

9 APPLICATIONS OF PHYTOCHEMICAL-SYNTHESISED AGNPS

Phytochemical-mediated silver nanoparticles (AgNPs) synthesized using *Acanthus ilicifolius* possess potent antimicrobial, antioxidant, antibiofilm, anticancer, catalytic, and environmental remediation properties. The bioactive metabolites present in *A. ilicifolius* (flavonoids, phenolics, alkaloids, tannins, and terpenoids) act as reducing and stabilizing agents, enhancing the functionality and biocompatibility of AgNPs. Recent studies have demonstrated their applications across biomedical, agricultural, food, and environmental sectors [132-133, 159].

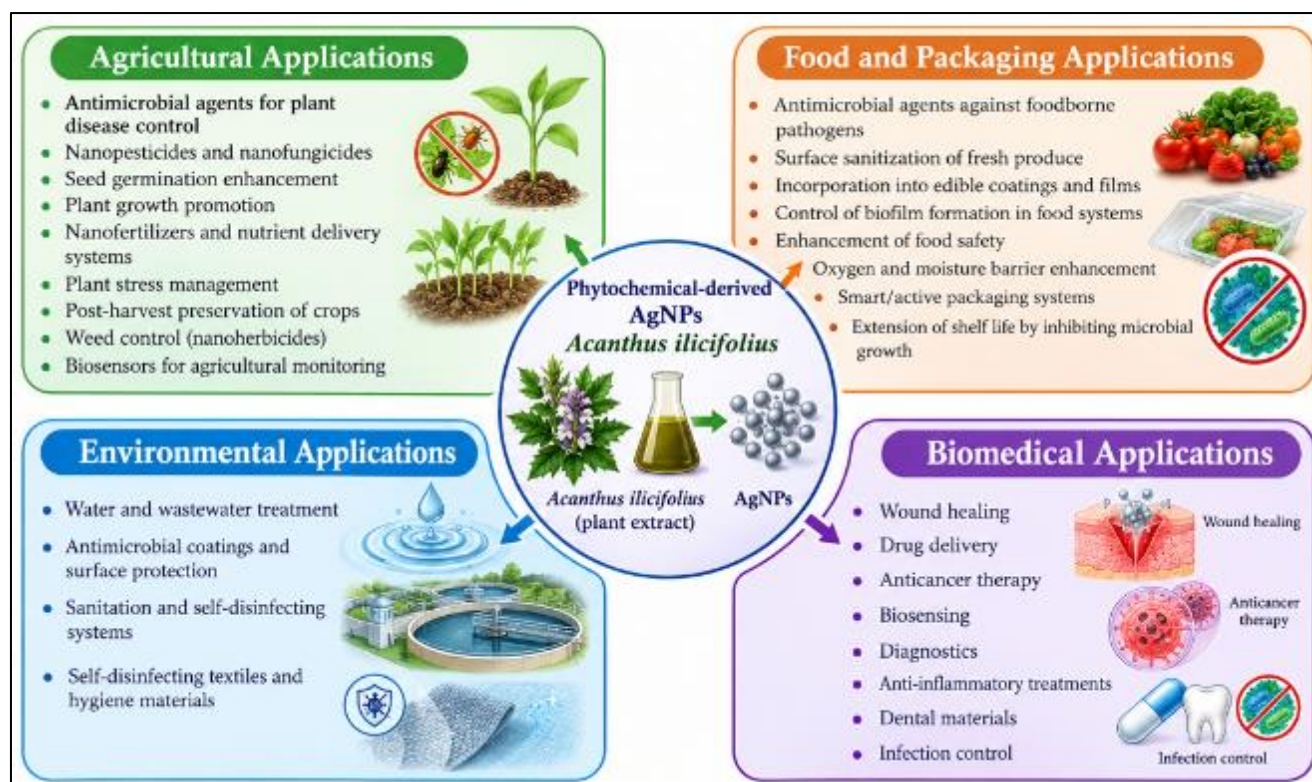


Figure 5: Schematic overview of the multifunctional applications of phytochemical-derived AgNPs.

9.1 Biomedical Applications

- Antibacterial and antifungal therapy
- Wound healing and tissue regeneration
- Drug delivery systems
- Anticancer activity against various cancer cell lines
- Biosensing and diagnostic platforms
- Anti-inflammatory applications
- Infection control in medical devices
- Recent studies on *A. ilicifolius*-derived AgNPs reported strong antibacterial activity against pathogenic microorganisms and significant antibiofilm effects, indicating their potential for therapeutic applications [134-135].

9.2 Agricultural Applications

- Plant disease management
- Nano-fertilizers and nutrient delivery systems
- Seed germination enhancement
- Crop growth promotion
- Nanopesticides and nanofungicides
- Post-harvest preservation
- Biosensors for agricultural monitoring
- Silver nanoparticles have been increasingly explored for disease suppression, nutrient uptake enhancement, and sustainable crop protection [136].

9.3 Food and Packaging Applications

- Antimicrobial food packaging materials
- Biofilm inhibition on food-contact surfaces
- Edible coatings and films
- Shelf-life extension of perishable foods
- Fresh produce sanitization
- Active and smart packaging systems

Plant-derived AgNPs exhibit broad-spectrum antimicrobial activity, making them attractive candidates for next-generation food packaging technologies [137].

9.4 Environmental Applications

- Water and wastewater treatment
- Removal of organic pollutants
- Antimicrobial coatings
- Self-disinfecting surfaces
- Air and soil remediation
- Antifouling membrane technologies

Recent reviews highlight the effectiveness of AgNPs in pollutant degradation, microbial disinfection, and environmental monitoring systems [138].

9.5 Future Research Directions

Compound Sea Holly Capsules (*A. ebracteatus*) is a certified product of Ministry of Public Health Thailand and has been indicated for relief of allergies and rashes. However, there is a scarcity of scientific evidence to establish safety or to support folklore claims for this mangrove plant. Structural analogs of 2-benzoxazolinone, a phytochemical of *A. ilicifolius*, have been claimed for weight loss, anorectic, mood enhancing property and as adjunctive in therapy for arthritis, sleep dysfunction, fibromyalgia and hyperglycemia [139]. Development of single herb formulations consisting of a full spectrum standardized herbal extract with established safety and efficacy studies conducted in accordance with scientific principles for above disorders could integrate use of this mangrove plant into clinical practice [131, 159].

10 CONCLUSION

In conclusion, *Acanthus ilicifolius*, a medicinal plant commonly found in coastal regions of tropical and subtropical countries, has been found to possess various pharmacological activities. These activities include anticancer, neuroprotective, cardioprotective, immunomodulatory, and wound-healing activities attributed to the plant's bioactive compounds, such as flavonoids, alkaloids, phenolics, and terpenoids. These compounds have been shown to exhibit antioxidant, anti-inflammatory, and immune-enhancing properties. However, despite the promising pharmacological activities of *Acanthus ilicifolius*, further research is needed to establish its safety, efficacy, and optimal usage in humans. Clinical trials are necessary to gather robust evidence on the potential benefits and risks of using *Acanthus ilicifolius* for medicinal purposes. It is important to consult a qualified healthcare professional before using *Acanthus ilicifolius* or any other herbal remedy, as proper dosage, duration of use, and potential interactions with other medications or health conditions must be considered. It has shown various pharmacological activities and possesses bioactive compounds with potential therapeutic properties. However, further research, including well-designed clinical trials, must establish its safety, efficacy, and optimal human usage. It is essential to seek professional advice before using *Acanthus ilicifolius* or any other herbal remedy for medicinal purposes. *Acanthus ilicifolius* is a promising medicinal mangrove plant rich in flavonoids, phenolics, tannins, alkaloids, terpenoids, saponins, glycosides, and polysaccharides. These phytochemicals function as natural reducing, capping, and stabilizing agents, making the plant an excellent candidate for the green synthesis of silver nanoparticles (AgNPs) and other metal nanoparticles. The resulting nanoparticles exhibit enhanced stability, biocompatibility, antioxidant activity, antimicrobial efficacy, and potential pharmaceutical applications.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors confirm they have no conflict of interest

REFERENCES

- [1] Wostmann R, Liebezeit G. Chemical composition of the mangrove holly *Acanthus ilicifolius* (Acanthaceae) - review and additional data. Senckenbergiana Maritime, 2008; 38: 31-37.

- [2] Liu L. et al., Synthesis and hepatoprotective properties of *Acanthus ilicifolius* alkaloid A and its derivatives. *Exp. Ther. Med.* 2013; 6: 796-802.
- [3] Bandaranayake WM. Traditional and medicinal uses of mangroves. *Mangroves and Salt Marshes.* 1998; 2: 133-148.1998. doi.org/10.1023/A:1009988607044.
- [4] Simlai A, Roy A. Biological activities and chemical constituents of some mangrove species from Sundarban estuary: An overview. *Pharmacogn Rev.* 2013; 7: 170-178.
- [5] Wang Y. et al., Polyphenols, tannins and antioxidant activities of eight true mangrove plant species in South China. *Plant Soil.* 2014; 549-563.
- [6] Wöstmann R, Liebezeit G. Chemical composition of the mangrove holly *Acanthus ilicifolius* (*Acanthaceae*) - review and additional data. *Senckenbergiana Maritime.* 2008; 38: 31-37. 2.
- [7] Liu L, et al., Synthesis and hepatoprotective properties of *Acanthus ilicifolius* alkaloid A and its derivatives. *Exp. Ther. Med.* 2013; 6: 796-802. 3.
- [8] Bandaranayake WM. Traditional and medicinal uses of mangroves. *Mangroves and Salt Marshes.* 1998; 2: 133-148.
- [9] Venugopal R, Liu RH. Phytochemicals in diets for breast cancer prevention: the importance of resveratrol and ursolic acid. *Food Sci Hum Wellness.* 2012; 1: 1–3.
- [10] Petropoulos SA, Karkanis A, Martins N, Ferreira IC. Halophytic herbs of the Mediterranean basin: an alternative approach to health. *Food Chem Toxicol.* 2018; 114: 155–69.
- [11] Park YJ, Park SY, Valan AM, Al-Dhabi NA, Ahn HG, Kim JK. Accumulation of carotenoids and metabolic profiling in different cultivars of Tagetes flowers. *Molecules.* 2017; 22: 313.
- [12] Abdullah AN, Valan AM, Rejiniemon TS. *In vitro* antibacterial, antifungal, antibiofilm, antioxidant, and anti-cancer properties of isosteviol isolated from endangered medicinal plant Pittosporum tetraspermum. *Evid Based Complement Altern Med.* 2015; 20: 15-17.
- [13] Arasu MV, Jeon J, Park YJ, Kwon SJ, Al-Dhabi NA, Park SU. Medically important carotenoids from *Momordica charantia* and their gene expressions in different organs. *Saudi J Biol Sci.* 2017; 24: 1913- 1919.
- [14] Surendra TV, Roopan SM, Al-Dhabi NA, Arasu MV, Sarkar G, Suthindhiran K. Vegetable peel waste for the production of ZnO nanoparticles and its toxicological efficiency, antifungal, hemolytic, and antibacterial activities. *Nanoscale Res Lett.* 2016; 11: 1–10.
- [15] Gamble JS, Fischer CE. Flora of the Presidency of Madras. Part 11. Addenda, corrigenda, indexes, etc. London: Ad Lord and Sons Limited; 1936.
- [16] Dalal S, Kataria SK, Sastry KV, Rana SV. Phytochemical screening of methanolic extract and antibacterial activity of active principles of hepatoprotective herb, *Eclipta alba*. *Ethnobot Leaflets.* 2010; 3.
- [17] Harborne AJ. Phytochemical methods a guide to modern techniques of plant analysis. Springer Science & Business Media; 1998. April 30.
- [18] Sofowora A. Medicinal plants and traditional medicine in Africa. John Willey & Sons New York; 1996.
- [19] Mani SK, Puia Z, Samanta SK, Barik R, Dutta A, Gorain B, Roy DK, Adhikari D, Karmakar S, Sen T. The gastroprotective role of *Acanthus ilicifolius* - A study to unravel the underlying mechanism of antiulcer activity. *Sci Pharm.* 2012; 80: 701-717
- [20] Surendra TV, Roopan SM, Arasu MV, Al-Dhabi NA, Rayalu GM. RSM optimized Moringa oleifera peel extract for green synthesis of *M. oleifera* capped palladium nanoparticles with antibacterial and hemolytic property. *J Photochem Photobiol B Biol.* 2016; 162: 550–7.
- [21] Armon D. Copper enzymes in isolated chloroplast. *Plant Physiol.* 1949; 24: 1-5.
- [22] Moore S, Stein WH. Colwick SP, Kaplan ND. Methods in enzymol. New York: Academic Press; 1948, 3: 468.
- [23] Mani SK, Puia Z, Samanta SK, Barik R, Dutta A, Gorain B, Roy DK, Adhikari D, Karmakar S, Sen T. Anti-inflammatory activity of *Acanthus ilicifolius*. *J Ethnopharmacol.* 2008; 120: 7-12.
- [24] Dey A, Raihan SM, Sariful SM, Hamiduzzaman M, Monjur ASM. Phytochemical screening and the evaluation of the antioxidant, cytotoxic and anti-microbial properties of *Acanthus ilicifolius* (Family: *Acanthaceae*). *Int. Res. J. Pharm.,* 2012; 3: 153-156.

- [25] Chakraborty TD, Bhuniya M, Chatterjee M, Rahaman D, Singha BN, Chatterjee S, Datta A, Rana K, Samanta S, Srivastawa SK, Chatterjee M. *Acanthus ilicifolius* plant extract prevents DNA alterations in a transplantable Ehrlich ascites carcinoma-bearing murine model. *World J Gastroenterol*. 2007; 13: 6538- 6548.
- [26] Raut S, Khan S. Phytochemical fingerprinting of *Acanthus ilicifolius* Linn. *Adv. Plant Sci*. 2012; 25: 749-753.
- [27] Wiffen P. Antidepressants and anticonvulsants for diabetic neuropathy and postherpetic neuralgia: a quantitative systematic review. *J Pain Symptom Manage*. 2000; 20: 449-458.
- [28] Sam J, Valentine JL. Preparation and properties of 2-benzoxazolinones. *Journal of Pharmaceutical Sciences*. 1969; 58: 1043-1054.
- [29] Babu BH, Shylesh BS, Padikkala J. Antioxidant and hepatoprotective effect of *Acanthus ilicifolius*. *Fitoterapia*. 2001; 72: 272-277.
- [30] Pamidiboina V, Razdan R, Hariprasad MG. Evaluation of the antihyperlipidemic, cardioprotective activity of a polyherbal formulation. *International Journal of Pharmacy and Pharmaceutical Sciences*. 2010; 2(1): 86–91.
- [31] Firdaus M, Prihanto AA, Nurdiani R, Widodo N. Antioxidant and cytotoxic activity of *Acanthus ilicifolius* flower. *Asian Pac J Trop Biomed*. 2013; 3: 17-21.
- [32] Babu BH, Shylesh BS, Padikkala J. Tumour reducing and anticarcinogenic activity of *Acanthus ilicifolius* in mice. *J Ethnopharmacol*. 2002; 79: 27-33.
- [33] Lichtenstein AH, Appel LJ, Brands M. Diet and lifestyle recommendations revision. *Circulation*. 2006; 114(1): 82–96.
- [34] Veeriah S, Kautenburger T, Habermann N. Apple flavonoids inhibit growth of HT29 human colon cancer cells and modulate expression of genes involved in the biotransformation of xenobiotics. *Molecular Carcinogenesis*. 2006; 45(3): 164–174.
- [35] T. Goto, N. Takahashi, S. Hirai, and T. Kawada. Various terpenoids derived from herbal and dietary plants function as PPAR modulators and regulate carbohydrate and lipid metabolism. *PPAR Research*. 2010; 1-9.
- [36] Singh D, Aeri V. Phytochemical and pharmacological potential of *Acanthus ilicifolius*. *J Pharm Bioall Sci* 2013; 5:17-20.
- [37] K T Mani Senthil Kumar et al., 2008. Anti-inflammatory activity of *Acanthus ilicifolius*, *Journal of Ethnopharmacology*, Vol 120, Issue 1, 30 October 2008, Pages 7-12 /doi:10.1016/j.jep.2008.07.024
- [38] Bose S, Bose A, Antimicrobial activity of *Acanthus ilicifolius* (L.) *Indian J Pharm Sci*. 2008; 70:821-3 / DOI:10.4103/0250-474X.49134.
- [39] Ganesh S. Vennila J. Screening for Antimicrobial Activity in *Acanthus ilicifolius* *Archives of Applied Science Research*, 2010. 2 (5):311-315.
- [40] Barry AL. The antimicrobial susceptibility test principle and practices. London: ELBS; p. 180. 1976.
- [41] G.Venkataiah, Mohammed Ishtiaq Ahmed, D. Sudharshan Reddy, Mary Rejeena. Anti-Diabetic Activity Of *Acanthus Illicifolius* Root Extract In Alloxan Induced Diabetic Rats, *Iajpr*. 2013;3(11):9007.
- [42] Kodama HA, Suda Y. Kasai H, Yamamoto S., Establishment of a clonal osteogenic cell line from newborn mouse calvaria. *Jpn. J. Oral Biol*. 1981; 23, 899–901.
- [43] Papoutsis, Z., Kassi, E., Mitakou, S., Aligiannis, N., Tsiapara, A., Chrousos, G., and Moutsatsou, P., 2006. Acteoside and martynoside exhibit estrogenic/antiestrogenic properties. *J. Steroid Biochem. Mol. Biol.*, 98, 63- 71.
- [44] Phan Van Kiem et al., Chemical constituents of *Acanthus ilicifolius* L. and effect on osteoblastic MC3T3E1 cells *Archives Of Pharmacal Research*. 2008; 31(7), 823-82. DOI 10.1007/s12272-001-1232-3.
- [45] Jiau-Jian L, Larry WO. Over expression of manganese-containing superoxide dismutase confers resistance to the cytotoxicity of tumour necrosis factor and/or hyperthermia. *Cancer Research*. 1977; 57, 1991–1998.
- [46] Ruby AJ. et al., Anti-tumour and antioxidant activity of natural curcuminoids. *Cancer Letters*. 1955; 94, 783.
- [47] Ming L. et al., Antioxidant action via p53 mediated apoptosis. *Cancer Research*. 1988 58, 1723–1729.
- [48] Putul M, SunitC, Pritha B. Neovascularisation offers a new perspective to glutamine related therapy. *Indian Journal of Experimental Biology*. 2000; 38, 88–90.
- [49] PlayerT. In: Mc Brein, D.C.H., Slater, T.F. (Eds.), *Free Radicals and Cancer*. Academic Press, London, pp. 173–195. 1982.

- [50] Frenkel K. Carcinogen mediated oxidant formation and oxidative DNA damage. *Pharmacology Therapy*. 53, 127–166. 1992.
- [51] Babu BH. et al., Antioxidant and hepatoprotective effect of *Acanthus ilicifolius*. *Fittoterapia*. 2001; 72 (3), 271–276.
- [52] Babu BH. et al., Tumour reducing and anticarcinogenic activity of *Acanthus ilicifolius* in mice, doi:10.1016/S0378-8741(01)00347-6, *Journal of Ethnopharmacology* Vol 79, Issue 1, 2002.
- [53] Spavieri J. et al. 2010. Antimycobacterial, antiprotozoal, and cytotoxic potential of twenty-one brown algae (Phaeophyceae) from British and Irish waters. *Phytother Res*. 2010; 24: 1724–1729.
- [54] Ara J, Sultana V, Ehteshamul-Haque S, Qasim R, Uddin V. Cytotoxic activity of marine macro-algae on *Artemia salina* (Brine shrimp). *Phytother Res*. 1999; 13: 304–307.
- [55] Babu BH, Shylesh BS, Padikkala J. Tumour reducing and anticarcinogenic activity of *Acanthus ilicifolius* in mice. *J Ethnopharmacol*. 2002; 79: 27–33.
- [56] Khajure PV, Rathod JL. 2011. Potential anticancer activity of *Acanthus ilicifolius* extracted from the mangroves forest of Karwar, West Coast of India. *World J Technol*; 1: 1–6.
- [57] Wostmann R, Liebezeit G. Chemical composition of the mangrove holly *Acanthus ilicifolius* (Acanthaceae). *Senckenbergiana*. 2008; 38: 31–37.
- [58] Tiwari P, Kumar B, Kaur M, Kaur G, Kaur H. Phytochemical screening and extraction. *Int Pharm Sci*. 2011; 1: 98–106.
- [59] Breton F, Cérantola S, Gall EA. Distribution and radical scavenging activity of phenols in *Ascophyllum nodosum* (Phaeophyceae). *J Exp Mar Biol Ecol*. 2011; 399: 167–172.
- [60] Nielsen MF, Ingold KU. Kinetic solvent effects on proton and hydrogen atom transfers from phenols. Similarities and differences. *J Am Chem Soc*. 2006; 128: 1172–1182.
- [61] Fernandez-Pachon MS, Berna G, Otaolaurruchi E, Troncoso AM, Martin F, Garcia-Parrilla MC. Changes in antioxidant endogenous enzymes (activity and gene expression levels) after repeated red wine intake. *J Agric Food Chem*. 2009; 57: 65780– 65783.
- [62] Hsu YW, Tsai CF, Chen WK, Huang CF, Yen CC. A sub-acute toxicity evaluation of green tea (*Camellia sinensis*) extract in mice. *Food Chem Toxicol*. 2011; 49: 2624–2630.
- [63] Chahar MK, Sharma N, Dobhal MP, Joshi Y. Flavonoids: A versatile source of anticancer drugs. *Pharmacog Rev*. 2011; 5: 1–12 29.
- [64] Man S, Gao W, Zhang Y, Huang L, Liu C. Chemical study and medical application of saponins as anticancer agents. *Fitoterapia*. 2010 81: 703–714.
- [65] Imai M, Kikuchi H, Denda T, Ohyama K, Hirobe C, Toyoda H. Cytotoxic effects of flavonoids against a human colon cancer derived cell line, COLO 201: A potential natural anti-cancer substance. *Cancer Lett*. 2009; 276: 74– 80.
- [66] Gonzalez-Sarrias A, Li L, Seeram NP. Anticancer effects of maple syrup phenolics and extracts on proliferation, apoptosis, and cell cycle arrest of human colon cells. *J Funct Foods*. 2011; doi:10.1016/j.jff.2011.10.004.
- [67] Gonzalez-Sarriás A, Espín JC, Tomas-Barberan FA, GarciaConesa MT. Gene expression, cell cycle arrest, and MAPK signalling regulation in Caco-2 cells exposed to ellagic and its metabolites, urolithins. *Mol Nutr Food Res*. 2009; 53: 686–698.
- [68] Muhamad Firdaus, Asep Awaludin Prihanto, Rahmi Nurdani. Antioxidant and Cytotoxic Activity of *Acanthus ilicifolius* Flower, *Asian Pac J Trop Biom ed*. Jan. 2013;3(1): 17–21. doi: 10.1016/S2221-1691(13)60017-9.
- [69] Ahmad Md. Sultan, Sheeba, Rai Kanchan B., Ali Afsar. *Acanthus ilicifolius* a Potent Anticarcinogen against Hydrocortisone-Induced Genotoxicity Study in Human Peripheral Lymphocytes Cultures, *Advances in Life Sciences*, Volume 1, Issue 1. 2012;
- [70] Kapil A, Sharma S, Wahidulla S. Leishmanicidal activity of 2-benzoxazolinone from *Acanthus ilicifolius* in vitro. *Planta Med*; 1994;60:187–8.
- [71] Nizamuddin BS, Danamma B, Chitta S, Mohd D, Abdul M. Evaluation of antiulcer activity in the methanol extract of *Acanthus ilicifolius* leaves in experimental rats. *Int J Pharm Ind Res*. 2011 1:57–62.
- [72] Van Kiem P, Quang TH, Huong TT, Nhung le LT, Cuong NX, Van Minh C, et al. Chemical constituents of *Acanthus ilicifolius* L. and effect on osteoblastic MC3T3E1 cells. *Arch Pharm Res* 2008;31:823–9.
- [73] Babu BH, Sylesh BS, Padikkala J. Antioxidant and hepatoprotective effect of *Acanthus ilicifolius*. *Fitoterapia* 2001;72:272–7.

- [74] Gulcan, H.O., E. Kupeli, S. Unlu, E. Yesilada and M.F. Sahin. 4-(5-chloro-2(3H)-benzoxazolon-3-yl) butanoic acid derivatives: synthesis, antinociceptive and anti-inflammatory properties. Arch Pharm (Weinheim). 2003; 336: 477-482.
- [75] Wang, Z., Y. Chen, G. Zheng, C. Yang and S. Long,. Anti-inflammatory and analgesic effects of *A. ilicifolius* alkaloids A and its derivatives acetyl ilicifolius alkaloids A. Zhongguo Yiyuan Yaouxue Zazhi. 2011; 31: 807-810.
- [76] Collins, S.L., R.A. Moore, H.J. McQuay and P. Wiffen. Antidepressants and anticonvulsants for diabetic neuropathy and postherpetic neuralgia: a quantitative systematic review. J Pain Symptom Manage. 2000; 20: 449-458.
- [77] SamJ, Valentine JL.Preparation and properties of 2-benzoxazolinones. Journal of Pharmaceutical Sciences. 1969; 58: 1043-1054.
- [78] MurtyMSR, Kamat SY. Isolation of 2-benzoxazolinone from *Acanthus ilicifolius*. Indian J. Pharm. Sci. 1984; 46: 218-219.
- [79] Kapil A. et al., Leishmanicidal activity of 2-benzoxazolinone from *Acanthus ilicifolius* in vitro. Planta Med. 1994; 60: 187-188.
- [80] Ahmed K. et al., Pharmacological evaluation of *Acanthus ilicifolius* L. root extract for asthmatic condition. Bangladesh J. Sci. Ind. Res. 2005; 40: 195-202.
- [81] Bandaranayake WM. Bioactivities, bioactive compounds and chemical constituents of mangrove plants. Wetlands Ecology and Management. 2002; 10: 421-452.
- [82] Batta AK. Et al., Stigmasterol reduces plasma cholesterol levels and inhibits hepatic synthesis and intestinal absorption in the rat. Metabolism. 2006; 55: 292-299.
- [83] BurgVK. et al., Plant sterols the better cholesterol in Alzheimer's disease? A mechanistical study. J Neurosci. 2013; 33: 16072-16087.
- [84] Dey A, Raihan SM, Sariful SM, Hamiduzzaman M, Monjur ASM. Phytochemical screening and the evaluation of the antioxidant, cytotoxic and anti-microbial properties of *Acanthus ilicifolius* (Family: *Acanthaceae*). Int. Res. J. Pharm., 2012; 3: 153-156.
- [85] Armon D. Copper enzymes in isolated chloroplast. Plant Physiol. 1949; 24: 1-5.
- [86] Wöstmann R, Liebezeit G. Chemical composition of the mangrove holly *Acanthus ilicifolius* (*Acanthaceae*) - review and additional data. Senckenbergiana Maritime. 2008; 38: 31-37. 2.
- [87] Ganesh S, Jannet J. Screening for anti-microbial activity in *Acanthus ilicifolius*. Arch Appl Sci Res. 2010; 2:311-315.
- [88] Nizamuddin BS, Danamma B, Chitta S, Mohd D, Abdul M. Evaluation of antiulcer activity in the methanol extract of *Acanthus ilicifolius* leaves in experimental rats. Int J Pharm Ind Res. 2011; 1:57–62 Lat. Am. J. Pharm. 42 (2): (2023).
- [89] Bandaranayake WM. Traditional and medicinal uses of mangroves. Mangroves and Salt Marshes, 1998; 2: 133-148.
- [90] Pamidiboina V, Razdan R, Hariprasad MG. Evaluation of the antihyperlipidemic, cardioprotective activity of a polyherbal formulation. International Journal of Pharmacy and Pharmaceutical Sciences. 2010; 2(1): 86–91.
- [91] Kapil A, Sharma S, Wahidulla S. Leishmanicidal activity of 2-benzoxazolinone from *Acanthus ilicifolius* in vitro. Planta Med. 1994; 60:187–8.
- [92] Surendra TV, Roopan SM, Arasu MV, Al-Dhabi NA, Rayalu GM. RSM optimized Moringa oleifera peel extract for green synthesis of M. oleifera capped palladium nanoparticles with antibacterial and hemolytic property. J Photochem Photobiol B Biol. 2016; 162: 550–7.
- [93] Firdaus M, Prihanto AA, Nurdiani R, Widodo N. Antioxidant and cytotoxic activity of *Acanthus ilicifolius* flower. Asian Pac J Trop Biomed. 2013; 3: 17-21.
- [94] Mastaller, M., J.R. Howes, J. Matthew and W. International Mangroves: the forgotten forest between land and sea: Tropical Press. 1997
- [95] Bandaranayake WM. Bioactivities, bioactive compounds and chemical constituents of mangrove plants. Wetlands Ecology and Management. 2002;10: 421-452.
- [96] GaneshS, Vennila JJ. Phytochemical analysis of *Acanthus ilicifolius* and *Avicennia officinalis* by GC-MS. Res. J. Phytochem. 2011; 5: 60-65.
- [97] DeyA. et al., Phytochemical screening and the evaluation of the antioxidant, cytotoxic and antimicrobial properties of *Acanthus ilicifolius* (Family: *Acanthaceae*). Int. Res. J. Pharm. 2012;3: 153-156.

- [98] Chakraborty TD. et al., *Acanthus ilicifolius* plant extract prevents DNA alterations in a transplantable Ehrlich ascites carcinoma-bearing murine model. World J Gastroenterol. 2007; 13: 6538-6548.
- [99] Bose S, Bose A. Antimicrobial activity of *Acanthus ilicifolius* (L.). Indian journal of pharmaceutical sciences. 2008; 70(6): 821-823. doi: 10.4103/0250- 474X.49134
- [100] Sardar PK, Dev S, Al Bari MA, Paul S, Yeasmin MS, Das AK, Biswas NN. Antiallergic, anthelmintic and cytotoxic potentials of dried aerial parts of *Acanthus ilicifolius* L. Clinical Phytoscience. 2018; 4(34): 1-3. doi: 10.1186/s40816-018-0094-7
- [101] Singh D, Aeri V. Phytochemical and pharmacological potential of *Acanthus ilicifolius*. Journal of Pharmacy & Bioallied Sciences. 2013; 5(1): 17. doi: 10.4103/0975-7406.106557
- [102] Babu BH, Shylesh BS, Padikkala J. Antioxidant and hepatoprotective effect of *Acanthus ilicifolius*. Fitoterapia. 2001; 72(3): 272-277. doi: 10.1016/ s0367-326x(00)00300-2
- [103] Bandaranayake WM. Bioactivities, bioactive compounds and chemical constituents of mangrove plants. Wetlands Ecology and Management. 2002; 10: 421-452. doi:10.1023/A:1021397624349
- [104] Saranya A, Ramanathan T, Kesavanarayanan KS, Adam A. Traditional medicinal uses, chemical constituents and biological activities of a mangrove plant, *Acanthus ilicifolius* Linn.: A brief review. American-Eurasian Journal of Agriculture and Environmental Science, 2015; 15: 243-250. doi: 10.5829/idosi.ajeaes.2015.15.2.12529 2
- [105] Andriani D, Revianti S, Prananingrum W. Identification of compounds isolated from a methanolic extract of *Acanthus ilicifolius* leaves and evaluation of their antifungal and antioxidant activity. Biodiversitas Journal of Biological Diversity. 2020; 21(6): 2521-2525. doi: <https://doi.org/10.13057/biodiv/d210625>
- [106] Giesen W, Wulffraat S, Zieren M, Scholten L. Mangrove guidebook for Southeast Asia. Mangrove guidebook for Southeast Asia. 2007.
- [107] Senthil Kumar KT, Puia Z, Samanta SK, Barik R, Dutta A, Gorain B, Roy DK, Adhikari D, Karmakar S, Sen T. The gastroprotective role of *Acanthus ilicifolius* – A study to unravel the underlying mechanism of anti-ulcer activity. Scientia Pharmaceutica. 2012; 80(3): 701-718. doi: 10.3797/scipharm.1108-11.
- [108] Zakaria NH. et al., Ethnobotany, phytochemistry and pharmacology of *Acanthus ilicifolius*: A comprehensive review. Malaysian Journal of Medicine and Health Sciences. 2024; 20(4), 333–344. <https://doi.org/10.47836/mjmhs.20.4.41>.
- [109] Sari Nindhia T, Gde Tirta Nindhia T, Nyoman Trisnawati N. Data on Potential of Indonesian variety of Sea holly (*Acanthus ilicifolius* Linn) as Herbal Medicine. In 2020 4th International Conference on Computational Biology and Bioinformatics. 2020; 27 (52-56).
- [110] Pattanaik C, Reddy CS, Dhal NK, Das R. Utilizations of mangrove forests in Bhitarkanika wildlife sanctuary, Orissa. Indian Journal of Traditional knowledge. 2008; 7(4): 598-603
- [111] Van Kiem P, Quang TH, Huong TT, Nhung LT, Cuong NX, Van Minh C, Choi EM, Kim YH. Chemical constituents of *Acanthus ilicifolius* L. and effect on osteoblastic MC3T3E1 cells. Archives of Pharmacal Research. 2008; 31: 823-829. doi: 10.1007/s12272-001-1232-3
- [112] Chakraborty T, Bhuniya D, Chatterjee M, Rahaman M, Singha D, Chatterjee BN, Datta S, Rana A, Samanta K, Srivastawa S, Maitra SK. *Acanthus ilicifolius* plant extract prevents DNA alterations in a transplantable Ehrlich ascites carcinoma-bearing murine model. World Journal of Gastroenterology: WJG. 2007; 12;13(48):6538.
- [113] Azam K, Nur M, Rahman MM, Biswas S, Ahmed MN. Appraisals of Bangladeshi medicinal plants used by folk medicine practitioners in the prevention and management of malignant neoplastic diseases. International Scholarly Research Notices Volume. 2016; 1-12. doi.org/10.1155/2016/7832120
- [114] Madureira MC, Martins AP, Salgueiro L, Paiva J, Proença da Cunha A. Medicinal plants, and traditional medicine in the Gulf of Guinea–S. Tomé and Príncipe islands. Recent progress in medicinal plants. 2002; 7: 361-381.
- [115] Giesen W, Wulffraat S, Zieren M, Scholten L. Mangrove guidebook for Southeast Asia. Mangrove guidebook for Southeast Asia. 2007; 769.
- [116] Bora R, Adhikari PP, Das AK, Raaman N, Sharma GD. Ethnomedicinal, phytochemical, and pharmacological aspects of genus *Acanthus*. International Journal of Pharmacy and Pharmaceutical Science. 2017; 9 (12): 18-25. doi:10.22159/ijpps.2017v9i12.22386.
- [117] Dube E. From plant metabolites to functional nanomaterials: Advances in phytochemical-mediated silver nanoparticle synthesis and applications. Micro. 2026; 6(2), 40. <https://doi.org/10.3390/micro6020040>.
- [118] Singh D, Aeri V. Phytochemical and Pharmacological Potential of *Acanthus ilicifolius*. Journal of Pharmacy and Bioallied Sciences. 2013;5(1):17–20.

- [119] Hasali NHM, et al. Ethnobotany, Phytochemistry and Pharmacology of *Acanthus ilicifolius*: A Comprehensive Review. Malaysian Journal of Medicine and Health Sciences. 2024.
- [120] Purwanto P, Irianto IDK, Wahyuni TS, Zakaria ZA. Chemistry and Biological Activities of *Acanthus ilicifolius*. Springer Nature; 2025.
- [121] Ghosh T, et al. Antioxidant and Cytotoxic Activity of *Acanthus ilicifolius* Flower. Asian Pacific Journal of Tropical Biomedicine. 2013;3(6):432–435.
- [122] Kanchanapoom T, Kasai R, Otsuka H, Yamasaki K. Lignan and Benzoxazinoid Glycosides from *Acanthus ilicifolius*. Phytochemistry. 2001;58:637–640.
- [123] Islam MT, Islam MS, Washim MMR, et al. Green Synthesis, Characterization and Antibacterial Activity of Silver Nanoparticles Using *Acanthus ilicifolius* Leaf Extract. Hybrid Advances. 2026;12:100620.
- [124] Mohanta YK, et al. Mangrove Pneumatophores as Biocatalysts for the Fabrication of Silver Nanoparticles and Their Potential Applications Against Biofilm Formation and Hepatic Carcinoma. Nanoscale Advances. 2025.
- [125] Ali A, et al. Biosynthesis and Characterization of Silver Nanoparticles Using *Acanthus ilicifolius* Leaf Extract. Reported in Mangroves and Nanobiotechnology.
- [126] Islam MT et al., Green synthesis, characterization and antibacterial activity of silver nanoparticles using *Acanthus ilicifolius* leaf extract. Hybrid Advances. 2026; 12, 100620. <https://doi.org/10.1016/j.hybadv.2026.100620>.
- [127] Zulfiqar Z, et al. From Plant Metabolites to Functional Nanomaterials: Advances in Phytochemical-Mediated Silver Nanoparticle Synthesis and Applications. Micro. 2025.
- [128] Hassanisaadi M, et al. Green Synthesis of Silver Nanoparticles Using Plant Extracts: A Comprehensive Review of Physicochemical Properties and Multifunctional Applications. Int J Mol Sci. 2024.
- [129] Ahmed S, et al. Green Synthesis of Silver Nanoparticles Using Medicinal Plants: Characterization and Application. J Radiat Res Appl Sci. 2022.
- [130] Banerjee P, et al. A Review of the Phytochemical Mediated Synthesis of AgNP. Applied Biochemistry and Biotechnology. 2021.
- [131] Xiong Q, et al., Impaired antioxidant defense associated with flavonoid biosynthesis reprogramming in the mangrove *Acanthus ilicifolius* under high salinity. Frontiers in Plant Science. 2026;17, 1853520. <https://doi.org/10.3389/fpls.2026.1853520>.
- [132] Junaidi, M. et al., Green synthesis, characterization and antibacterial activity of silver nanoparticles using *Acanthus ilicifolius* leaf extract. Hybrid Advances. 2026; 12, 100620. <https://doi.org/10.1016/j.hybadv.2026.100620>
- [133] Mohanta YK. et al., Mangrove pneumatophores as biocatalysts for the fabrication of silver nanoparticles and their potential applications against biofilm formation and hepatic carcinoma. Nanoscale Advances. 2025. <https://doi.org/10.1039/D4NA00722K>
- [134] Prajapati S. et al., Environmental applications of silver nanoparticles: State-of-the-art review and emerging trends. Beilstein Journal of Nanotechnology. 2026; 17, 697–736. <https://doi.org/10.3762/bjnano.17.49>
- [135] Selvam R, Gengan S. Synthesis of Silver Nanoparticles for Environmental and Agricultural Applications. Chemistry & Biodiversity. 2026; 23(7), e71486. <https://doi.org/10.1002/cbdv.71486>
- [136] Kumarasamy RV. et al., Sustainable biogenic synthesis of silver nanoparticles for oral cancer: A comprehensive review. Frontiers in Nanotechnology. 2026 7, 1648900. <https://doi.org/10.3389/fnano.2025.1648900>
- [137] Hosny S. et al., A Comprehensive Review of Silver Nanoparticles (AgNPs): Synthesis Strategies, Toxicity Concerns, Biomedical Applications, AI-Driven Advancements, Challenges, and Future Perspectives. Arabian Journal for Science and Engineering. 2026; 51, 13667–13714.
- [138] Eker F. et al., Green Synthesis of Silver Nanoparticles Using Plant Extracts: A Comprehensive Review of Physicochemical Properties and Multifunctional Applications. International Journal of Molecular Sciences, 2025; 26(13), 6222.
- [139] Rosenfeld MJ, Forsberg SR. Compounds for use in weight loss and appetite 58. Kanchanapoom, T., M.S. Kamel, R. Kasai, suppression in humans, Google Patents. 2009. 58: 363–364.
- [140] Zakaria ZA, Patahuddin H, Mohamad AS, Israf DA, Sulaiman MR. In vivo anti-nociceptive and anti-inflammatory activities of the aqueous extract of the leaves of *Acanthus ilicifolius* L. Journal of Ethnopharmacology. 2005;97(1):89–93.

- [141] Bandaranayake WM. Traditional and medicinal uses of mangroves. *Mangroves and Salt Marshes*. 1998;2:133–148.
- [142] Singh A, Duggal S, Sutttee A. *Acanthus ilicifolius* Linn.—lesser known medicinal plant with significant pharmacological potential. *International Journal of Green Pharmacy*. 2009;3(4):283–286.
- [143] **Gupta D**, Shrivastav SK, Malviya R.K. Nanoliposome: An overview of types, preparation, evaluation and application. *Int. J. of Pharm. & Life Sci*. 2022;13(1): 15-34.
- [144] Singh Gurjar NP, Sharma SK, Gupta D, Vengurlekar S. Gastroretentive microballoons for oral drug delivery: formulation strategies, mechanistic insights, evaluation, clinical translation, and future perspectives. *J Front Multidiscip Res*. 2026;7(2):155-162. doi:10.54660/JFMR.2026.7.2.155-162.
- [145] Patil G, Gupta D, Dr. Vengurlekar S, Dr. Jain SK. Design and Characterization of a Novel Nanocarrier System for Enhanced Dissolution and Bioavailability of Efinaconazole. *Journal of Advances in Drug Discovery and Development*. 2026; 4(2), 92– 108. <https://doi.org/10.5281/zenodo.21189247>.
- [146] ChaurasiyaUK, Gupta D, VengurlekarS, JainK. A review: Polymer-based nanoparticles as oral anticancer drug delivery systems. *International Journal for Research Trends and Innovation*. 2025; 10(10).
- [147] Bhat VG, Masti SP, Narasagounder SS, Kurabetta LK, Gunaki MN, Hunashyal AA, Chougale RB, **Malabadi RB**. Antimicrobial silver nanoparticle-doped poly(vinyl alcohol)/guar gum/gum ghatti nanocomposites: A multifaceted step towards sustainable packaging. *Sustainable Food Technology*. The Royal Society of Chemistry. 2026;DOI: 10.1039/d5fb00825e.
- [148] Malabadi RB, Saini I, Chalannavar RK. Role of Nanoparticles in Plant Tissue Culture. *Magna Scientia Advanced Biology and Pharmacy*. 2026; 17:2:52-68.
- [149] Kolkar KP, Malabadi RB, Nethravathi TL, Chalannavar RK. Application of Nanotechnology, Artificial Intelligence (AI) and use of Yeast extract in Plant Tissue Culture: An Updated Review. *International Journal of Science and Research Archive*. 2025; 17(02); 230-247.
- [150] Kolkar KP, **Malabadi RB**, Sadiya MR, Chalannavar RK. Updates on some medicinal and ornamental plants- *Ayurvedic* medicines. *World Journal of Advanced Research and Reviews*. 2024; 23(01): 111–147.
- [151] MalabadiRB, Kolkar KP, Meti NT, Chalannavar RK. Vaccine development for coronavirus (SARS-CoV-2) disease (Covid-19); Lipid nanoparticles. *International Journal of Research and Scientific Innovations*. 2021; 8(3): 189-195 (DOI: dx.doi.org/10.51244/IJRSL.2021.8312).
- [152] Nityasree BR, Chalannavar RK, Kouser S, Divakar MS, Gani RS, Sowmyashree K, Malabadi RB. Bioinspired synthesis of zinc oxide nanoparticles by using leaf extract of *Solanum lycopersicum* L. for larvicidal activity of *Aedes aegypti* L. *Advances in Natural Sciences: Nanoscience and Nanotechnology*. 2021;12(1):1-8. (<https://doi.org/10.1088/2043-6262/abeaae>).
- [153] Khan SR, Ganguly A, MalabadiRB, Sunwoo HH, Parashar A, Teixeira da Silva JA, Mavanur RS. Targeting strategies and nanocarriers in vaccines and therapeutics. *Research in Biotechnology*. 2011; 2(6):08-20.
- [154] Malabadi RB, Chalannavar RK, Meti NT, Mulgund GS, Nataraja K, Vijayakumar S. Synthesis of antimicrobial silver nanoparticles by callus cultures and in vitro derived plants of *Catharanthus roseus*. *Research in Pharmacy*. 2012; 2(6):18- 31.
- [155] **Malabadi RB**, Meti NT, Mulgund GS, Nataraja K, Vijayakumar S. Synthesis of silver nanoparticles from in vitro derived plants and callus cultures of *Costus speciosus* (Koen.): Assessment of antibacterial activity. *Research in Plant Biology*. 2012; 2(4): 32-42.
- [156] **Malabadi RB**, Mulgund GS, Meti NT, Nataraja K, Vijayakumar S. Antibacterial activity of silver nanoparticles synthesized from whole plant extracts of *Clitoria ternatea*. *Research in Pharmacy*. 2012; 2(4):11-21
- [157] Malabadi RB, Lokare-Naik S, Meti NT, Mulgund GS, Nataraja K, Vijayakumar S. Synthesis of silver nanoparticles from in vitro derived plants and callus cultures of *Clitoria ternatea*; Evaluation of antimicrobial activity. *Research in Biotechnology*. 2012; 3(5): 26-38.
- [158] MalabadiRB, Meti NT, Chalannavar RK. Applications of nanotechnology in vaccine development for coronavirus (SARS-CoV-2) disease (Covid-19). *International Journal of Research and Scientific Innovations*. 2021; 8(2): 191-198.
- [159] Singh D, Aeri V. Phytochemical and pharmacological potential of *Acanthus ilicifolius*. *J. Pharm Bioallied Sci*. 2013 Jan;5(1):17-20. doi: 10.4103/0975-7406.106557.
- [160] TupeA, Gupta D, Vengurlekar S, Jain SK. Intranasal mucoadhesive nanoemulsion of donepezil for brain targeting in Alzheimer's disease: A review. *International Journal of Novel Trends in Innovation (IJNTI)*. 2026; 4(6).