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Review Article

CROSSANDRA INFUNDIBULIFORMIS (L.) NEES: AN UPDATED REVIEW OF ETHNOBOTANY, PHYTOCHEMISTRY, PHARMACOGNOSY, PHARMACOLOGICAL ACTIVITIES AND THERAPEUTIC POTENTIAL

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ABSTRACT

Crossandrainfundibuliformis (L.) Nees, belonging to the family Acanthaceae, is a perennial tropical ornamental shrub popularly known as the firecracker flower. Although widely cultivated for its attractive orange flowers and ornamental importance, the plant has also received considerable attention because of its traditional medicinal applications and diverse pharmacological properties. Different parts of the plant, particularly leaves, flowers and aerial parts, have been investigated for antimicrobial, antioxidant, hepatoprotective, anti-inflammatory, analgesic, antidiabetic, anthelmintic, aphrodisiac, anticancer, anti-tubercular, wound-healing, anti-solar and anti-ulcer activities. Phytochemical investigations have demonstrated the presence of alkaloids, flavonoids, phenolic compounds, tannins, saponins, terpenoids, steroids, glycosides, carbohydrates and other secondary metabolites. Apigenin has also been reported in phytochemical databases associated with the species. Recent research has extended the pharmacological relevance of the plant to nanoparticulate drug delivery, green synthesis of metallic nanoparticles, cellular wound-healing models and GC–MS-based characterization. Experimental studies suggest that antioxidant and antimicrobial mechanisms may contribute to several of its biological effects. However, much of the available evidence remains based on crude extracts and preliminary in-vitro or animal studies, with limited information concerning isolated active compounds, molecular mechanisms, pharmacokinetics, standardized extracts, toxicity, clinical efficacy and quality control. This review summarizes the botanical characteristics, ethnomedicinal importance, pharmacognostic features, phytochemical composition, pharmacological activities, formulation approaches and future research perspectives of C. infundibuliformis. The available evidence supports further systematic investigation of this plant as a potential source of bioactive molecules and standardized herbal preparations.

Keywords: Crossandrainfundibuliformis, Acanthaceae, firecracker flower, phytochemistry, pharmacognosy, antioxidant, antimicrobial, hepatoprotective, antidiabetic, wound healing, herbal medicine, nanotechnology.

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1. INTRODUCTION

Medicinal plants constitute an important source of structurally diverse natural products and continue to contribute to the discovery of pharmacologically active compounds. Plants of the family Acanthaceae have traditionally been used for numerous therapeutic purposes and have attracted considerable pharmacological and phytochemical interest. Crossandrainfundibuliformis (L.) Nees is one such species that combines substantial horticultural importance with traditional medicinal value.

Crossandrainfundibuliformis is commonly known as firecracker flower because of the characteristic explosive opening of its mature seed capsules under humid conditions. It is an evergreen or perennial tropical plant cultivated extensively in southern India and other tropical and subtropical regions. The attractive flowers are widely used in ornamental horticulture and traditional garlands. The species is also reported from Sri Lanka and other parts of tropical Asia (Sumalatha, 2012; Hari Vishva et al., 2022).

Traditional applications of C. infundibuliformis include the management of various disorders involving the skin, gastrointestinal system, infections, inflammation and reproductive health. These ethnomedicinal claims have stimulated experimental investigations of different plant parts and extracts. Studies have reported antimicrobial, antioxidant, hepatoprotective, antidiabetic, anti-inflammatory, analgesic, aphrodisiac, anticancer, anti-tubercular, wound-healing, anti-solar and anthelmintic activities (Madhumitha & Saral, 2011; Sharmila & Gomathi, 2011; Kumar et al., 2010; Vadivel &Panwal, 2016).

Importantly, the pharmacological literature has progressively expanded from preliminary phytochemical screening toward formulation development, cellular models, nanotechnology and chromatographic profiling. A 2017 study investigated a PLGA nanoparticulate hydrogel containing C. infundibuliformis extract, while a 2025 study explored the green synthesis of copper nanoparticles using its leaves. More recently, a 2026 study employed GC–MS, antimicrobial, antioxidant, hemolytic and molecular-docking approaches to investigate the aqueous leaf extract (Jyothi et al., 2017; Philip et al., 2025; Mulla et al., 2026).

The present review therefore aims to provide an updated and comprehensive account of the botanical identity, ethnomedicinal significance, pharmacognostic characteristics, phytochemistry, pharmacological activities, formulation approaches, safety considerations and future research potential of C. infundibuliformis.

Taxonomical Classification

Taxonomic category	Classification
Kingdom	Plantae
Clade	Angiosperms
Order	Lamiales
Family	Acanthaceae
Genus	Crossandra
Species	Crossandrainfundibuliformis (L.) Nees

The currently accepted botanical name is Crossandrainfundibuliformis (L.) Nees. Synonyms reported in plant databases include Crossandraundulaefolia and Justicia infundibuliformis. The species belongs to Acanthaceae and is recognized as an ornamental tropical plant (Kew Science, 2026; IMPPAT, 2026).

Botanical Description

Crossandrainfundibuliformis is generally an erect, branched perennial or subshrub reaching approximately 60–90 cm in height. The stem is generally cylindrical to slightly angular and may be pubescent, particularly toward younger portions. Leaves are simple, green, opposite or apparently arranged in whorls because of short internodes. They are ovate-oblong to lanceolate, with entire or slightly undulate margins.

The inflorescence is terminal and characteristically spike-like. Flowers are bright orange to reddish-orange, tubular and funnel-shaped, which explains the specific epithet infundibuliformis, meaning funnel-shaped. The corolla has a characteristic expanded limb and several lobes. The fruit is a capsule containing seeds possessing hygroscopic hairs or structures that facilitate seed dispersal under humid conditions.

Detailed pharmacognostic investigations have described the macroscopic and microscopic characteristics of the root, stem and leaves, including epidermal structures, cortical organization, vascular tissues, trichomes and other diagnostic characters (Sumalatha, 2012; Hari Vishva et al., 2022).

Geographical Distribution and Cultivation

The species is associated primarily with tropical and subtropical regions. It is native to India and Sri Lanka and is widely cultivated in southern India. It is particularly important as a commercial ornamental crop because of its attractive flowers and suitability for warm climates.

The plant can be propagated through seeds and vegetative methods such as stem cuttings. Good drainage, warm temperatures and adequate sunlight support growth and flowering. Because the plant has both horticultural and medicinal significance, cultivation under controlled conditions could also provide a reproducible source of raw material for pharmacological investigations.

Recent horticultural research has demonstrated considerable variability among Crossandra genotypes with respect to flower colour, pigmentation and bioactive characteristics, suggesting opportunities for selection and breeding of varieties with enhanced ornamental and phytochemical properties (Reddy et al., 2026).

Ethnomedicinal Importance

Traditional use provides an important starting point for pharmacological investigation. C. infundibuliformis has been associated with several traditional applications in Indian systems of medicine and folk practices.

Different plant parts have traditionally been employed for conditions involving:

- inflammatory disorders,
- skin problems,
- wounds,
- microbial infections,
- gastrointestinal disorders,
- diabetes,
- reproductive disorders,

- liver disorders,
- and other general health conditions.

The plant is also culturally important because its flowers are used in garlands and as hair adornments. Traditional use among certain Indian communities has been documented in ethnobotanical literature (Shanmugam et al., 2009).

Experimental studies have subsequently investigated several of these traditional claims, particularly antimicrobial, antioxidant, hepatoprotective, aphrodisiac, anti-inflammatory and wound-healing activities.

Pharmacognostic Characteristics

Pharmacognostic evaluation is essential for authentication and quality control of medicinal plant materials. Sumalatha (2012) conducted pharmacognostic and phytochemical investigations of C. infundibuliformis leaves and emphasized the importance of morphological, anatomical and physicochemical parameters for identification and standardization.

Macroscopic characteristics

Leaves are generally:

- green,
- ovate-oblong,
- entire or slightly undulate,
- glabrous or sparsely pubescent,
- provided with a distinct petiole.

The flowers are bright orange and arranged in terminal spikes.

Microscopic characteristics

Microscopic examination of plant tissues has demonstrated characteristic epidermal and vascular structures. The stem possesses an epidermis with cuticle and trichomes, followed by cortical tissue and a vascular system. Root sections demonstrate cork, cortex, endodermal regions and vascular tissues (Sumalatha, 2012).

Such anatomical characteristics can be useful in detecting adulteration and establishing botanical identity.

Importance of standardization

For development of C. infundibuliformis as a herbal drug, the following parameters should be established:

1. Macroscopic identification.
2. Microscopic identification.
3. Foreign matter determination.
4. Moisture content.
5. Total ash.
6. Acid-insoluble ash.
7. Water-soluble ash.
8. Extractive values.
9. Preliminary phytochemical profile.
10. HPTLC/HPLC fingerprinting.
11. Quantification of marker compounds.
12. Microbial-load testing.
13. Heavy-metal analysis.
14. Pesticide-residue analysis.

Phytochemical Profile

Phytochemical screening represents one of the most extensively investigated aspects of C. infundibuliformis. Extracts prepared using different solvents have demonstrated considerable variation in phytochemical composition.

Reported classes include:

- alkaloids,
- flavonoids,
- phenolic compounds,
- tannins,
- saponins,
- terpenoids,
- steroids,
- glycosides,
- carbohydrates,
- proteins,
- fixed oils,
- volatile constituents,
- phytosterols.

Madhumitha and Saral (2011) reported alkaloids, saponins, phytosterols, phenolic compounds, flavonoids, tannins, carbohydrates, terpenoids, oils and fats in successive leaf extracts. Sharmila and Gomathi (2011) also reported flavonoids, saponins, terpenoids, cardiac glycosides, reducing sugars and tannins.

Elamathi et al. (2011) identified carbohydrates, alkaloids, steroids, tannins, phenols, saponins, fixed oils and fats, gums and mucilage, proteins, flavonoids and volatile oils in leaf extracts.

A curated Indian medicinal-plant database has specifically associated apigenin with the leaves of C. infundibuliformis, indicating that individual flavonoids may contribute to the biological properties of the plant.

Table 1. Major phytochemical classes reported from C. infundibuliformis

Phytochemical class	Reported plant material	Possible pharmacological relevance
Alkaloids	Leaves	Antimicrobial, antioxidant and other bioactivities
Flavonoids	Leaves/flowers	Antioxidant, anti-inflammatory
Phenolics	Leaves/flowers	Antioxidant, antimicrobial
Tannins	Leaves/flowers	Antimicrobial, antioxidant, astringent
Saponins	Leaves	Antimicrobial and other biological effects
Terpenoids	Leaves	Antioxidant, antimicrobial, anti-inflammatory
Steroids/phytosterols	Leaves	Diverse pharmacological effects
Glycosides	Leaves/flowers	Various biological activities
Carbohydrates	Leaves	Nutritional/phytochemical constituents
Volatile constituents	Leaves	Potential antimicrobial and aromatic effects

Importantly, qualitative phytochemical screening should not be interpreted as proof that a particular constituent is responsible for a pharmacological effect. Bioactivity-guided fractionation and quantitative chemical characterization are required to establish causal relationships.

Recent GC–MS-Based Phytochemical Characterization

An important development in the field is the application of modern analytical techniques. Mulla et al. (2026) investigated aqueous leaf extract of C. infundibuliformis using GC–MS and reported 20 phytocompounds in the analyzed extract. The study also combined phytochemical characterization with antimicrobial, antioxidant, hemolytic and computational investigations.

The aqueous extract demonstrated dose-dependent DPPH radical-scavenging activity, with an IC50 of approximately 43.43 µg/mL compared with 33.4 µg/mL for ascorbic acid. The extract showed antimicrobial activity against tested bacterial strains, while hemolytic activity remained below 45% at the highest tested concentration. Molecular docking suggested favorable interactions of selected compounds with COX-1, NF-κB and TNF-α targets (Mulla et al., 2026).

These findings are particularly relevant because they represent a transition from traditional preliminary phytochemical screening toward integrated analytical and computational pharmacology.

Pharmacological Activities

Antioxidant Activity

Oxidative stress is implicated in numerous pathological conditions, including inflammation, diabetes, hepatic injury and tissue damage. The presence of flavonoids, phenolics and tannins provides a plausible chemical basis for antioxidant activity.

Sharmila and Gomathi (2011) reported antioxidant activity of C. infundibuliformis leaf extracts. The ethanolic extract demonstrated substantial free-radical-scavenging activity, with reported inhibition of approximately 89.27% at the tested concentration.

The antioxidant activity may be associated with the ability of phenolic and flavonoid compounds to donate hydrogen or electrons and stabilize free radicals.

More recently, Mulla et al. (2026) confirmed dose-dependent DPPH radical-scavenging activity in aqueous leaf extract, supporting earlier observations.

Potential mechanisms

Possible mechanisms include:

- free-radical scavenging,
- inhibition of lipid peroxidation,
- metal-ion chelation,
- enhancement of endogenous antioxidant defense,
- reduction of oxidative stress-mediated cellular injury.

However, detailed in-vivo antioxidant investigations remain limited.

Antibacterial Activity

Antibacterial activity is among the better documented pharmacological properties of C. infundibuliformis.

Madhumitha and Saral (2011) evaluated successive leaf extracts against bacterial organisms and reported antibacterial activity with MIC values in the range of 0.0078–0.0150 µg/mL under their experimental conditions.

Sharmila and Gomathi (2011) evaluated ethanol, petroleum ether and aqueous extracts against several pathogenic bacteria, including Shigella dysenteriae, Pseudomonas aeruginosa, Serratia marcescens, Salmonella typhimurium, Proteus mirabilis and Staphylococcus aureus. The ethanol extract demonstrated activity against the organisms investigated.

Elamathi et al. (2011) similarly reported antibacterial activity of methanolic and aqueous leaf extracts, with considerable inhibition observed against selected bacterial strains.

The observed activity may be related to flavonoids, tannins, phenolics, terpenoids and other secondary metabolites.

Antifungal and Anticandidal Activity

Madhumitha and Saral (2011) also investigated antifungal and anticandidal properties of successive

extracts. MIC values for antifungal and anticandidal activity were reported in the range of approximately 0.125–0.250 µg/mL under the conditions of that study.

These findings suggest that C. infundibuliformis contains constituents capable of interfering with fungal growth.

Potential mechanisms may involve:
- disruption of fungal cell membranes,
- interaction with membrane proteins,
- inhibition of fungal metabolic enzymes,
- oxidative damage,
- interference with cellular signaling.

Further studies using purified compounds and clinically relevant resistant fungal strains would strengthen this evidence.

Anti-Tubercular Activity

Satheesh Kumar et al. (2018) investigated leaf and flower extracts of C. infundibuliformis against Mycobacterium tuberculosis using the Alamar Blue assay.

Methanolic flower extract and ethyl acetate leaf extract demonstrated activity, with a reported MIC of 3.12 µg/mL under the experimental conditions.

The study suggested that secondary metabolites such as phenolics, alkaloids, glycosides and tannins may contribute to the observed antimycobacterial activity.

Nevertheless, the evidence remains preliminary because crude extracts were used. Confirmation against drug-sensitive and drug-resistant clinical isolates and identification of active molecules are required.

Hepatoprotective Activity

Madhumitha et al. (2010) investigated the hepatoprotective potential of petroleum ether leaf extract of C. infundibuliformis against carbon tetrachloride-induced hepatotoxicity in mice.

The extract produced significant hepatoprotective effects based on biochemical liver-function parameters and was compared with silymarin. The findings provide experimental support for the traditional relevance of the plant to hepatic disorders.

The hepatoprotective effect may be related to antioxidant activity, inhibition of lipid peroxidation and stabilization of hepatic cellular membranes.

Further studies should examine:
- ALT,
- AST,
- ALP,
- bilirubin,
- glutathione,
- catalase,
- superoxide dismutase,
- lipid peroxidation,
- inflammatory cytokines,
- histopathology,
- Nrf2/HO-1 signaling.

Antidiabetic Activity

The antidiabetic potential of C. infundibuliformis has been investigated using both enzyme-based and animal models.

Vadivel and Panwal (2016) investigated the ethanolic leaf extract against α-amylase and reported concentration-dependent inhibitory activity.

More importantly, Galanki et al. (2020) evaluated ethanolic leaf and stem extracts in alloxan-induced diabetic rats. Treatment was associated with reductions in blood glucose, total cholesterol and triglycerides, together with an increase in HDL cholesterol. Changes in antioxidant parameters and histopathology of the liver and kidney were also investigated.

These findings suggest that C. infundibuliformis may exert antidiabetic effects through multiple mechanisms, including:
- inhibition of carbohydrate-digesting enzymes,
- reduction of oxidative stress,
- improvement of lipid metabolism,
- possible preservation of tissue antioxidant defenses.

However, evidence concerning insulin secretion, insulin sensitivity, GLUT4 signaling, AMPK activation and pancreatic β-cell protection remains insufficient.

Anthelmintic Activity

Vadivel and Panwal (2016) evaluated ethanolic leaf extract against the Indian earthworm Eudriluseugeniae as an experimental model.

The extract produced concentration-dependent anthelmintic activity, with the highest concentration producing the greatest effect.

The activity may potentially be related to tannins, saponins, alkaloids and other secondary metabolites. Nevertheless, earthworm assays are preliminary screening models and cannot substitute for studies against clinically important helminths.

Anti-inflammatory Activity

Inflammation is a complex biological process involving mediators such as prostaglandins, cytokines, NF-κB and inflammatory enzymes.

Dhamija et al. (2015) investigated the anti-inflammatory activity of methanolic floral extract of C. infundibuliformis using experimental models of acute and chronic inflammation. The findings indicated anti-inflammatory potential.

In-vitro anti-arthritic activity has also been evaluated using inhibition of protein denaturation. Sreevani et al. reported concentration-dependent inhibition by petroleum ether and methanolic leaf extracts.

The anti-inflammatory effects could potentially involve:

- inhibition of COX pathways,
- suppression of inflammatory cytokines,
- inhibition of protein denaturation,
- antioxidant effects,
- modulation of NF-κBsignaling.

The 2026 GC–MS/in-silico study further suggested potential interactions of identified compounds with COX-1, NF-κB and TNF-α targets, although computational findings require experimental validation (Mulla et al., 2026).

Analgesic Activity

Jayaveera et al. (2012) investigated analgesic and anti-inflammatory properties of C. infundibuliformis leaf extract. The findings reported pharmacological activity supporting the traditional use of the plant for inflammatory and painful conditions.

Analgesic activity may result from modulation of peripheral inflammatory mediators or central pain pathways. However, additional studies using standardized extracts and mechanistic biomarkers are necessary to determine whether the analgesic activity is primarily peripheral, central or secondary to anti-inflammatory action.

Anti-arthritic Activity

In-vitro anti-arthritic potential has been investigated using inhibition of egg-albumin-induced protein denaturation.

Sreevani et al. reported inhibition of protein denaturation by both petroleum ether and methanolic extracts, with greater activity reported for the petroleum ether extract at the investigated concentrations.

Because protein-denaturation assays are screening methods, these findings should be considered preliminary. Future investigations should employ validated animal models of rheumatoid arthritis and assess cytokines, oxidative stress markers, cartilage degradation and inflammatory pathways.

Aphrodisiac Activity

Saravana Kumar et al. (2010) investigated the aphrodisiac potential of petroleum ether leaf extract in ethanol-induced testicular toxicity in male rats.

The study reported improvements in sexual behavioral parameters, including mount and intromission frequency, along with changes in ejaculation latency. Serum testosterone concentrations were also increased in treated groups.

The study suggested that the observed effects might be associated with improved testosterone status and reproductive function.

Nevertheless, systematic investigations involving sperm parameters, Leydig-cell function, steroidogenic enzymes, oxidative stress and reproductive histology are required before drawing conclusions concerning therapeutic reproductive applications.

Anticancer Activity

Vadivel and Panwal (2016) investigated the anticancer activity of ethanolic leaf extract using the MCF-7 human breast cancer cell line.

The study reported concentration-dependent cytotoxic activity, with an IC50 of approximately 404.66 µg/mL.

This finding indicates preliminary cytotoxic potential but does not establish clinical anticancer efficacy. Crude plant extracts often contain multiple compounds, and cytotoxicity at relatively high concentrations may not necessarily indicate selective anticancer activity.

Future research should compare:

- cancer versus normal cells,
- apoptosis,
- mitochondrial membrane potential,
- caspase activation,
- cell-cycle distribution,
- ROS generation,
- molecular targets,
- and activity of purified compounds.

Insecticidal and Larvicidal Activity

Crossandrainfundibuliformis has also been investigated for insect-control applications.

Madhumitha and Saral (2012) evaluated larvicidal activity against mosquito species including Anopheles stephensi, Aedes aegypti and Culex quinquefasciatus.

Vadivel and Panwal (2016) also evaluated insecticidal activity against the wheat weevil Sitophilus oryzae. Their ethanolic leaf extract showed concentration-dependent insecticidal activity, with complete mortality reported at selected concentrations.

These findings indicate possible agricultural and vector-control applications. However, environmental safety, non-target toxicity and active-compound identification require detailed evaluation.

Anti-solar Activity

The flowers of C. infundibuliformis have been investigated for potential use as a natural anti-solar or sunscreen ingredient.

Vadlamudi et al. (2014) evaluated aqueous extracts of fresh and dried flowers using UV-visible spectrophotometry over the 200–400 nm range. The fresh flower extract showed stronger UV absorption than the dried flower preparation.

The potential mechanism may be associated with phenolic and flavonoid compounds capable of absorbing UV radiation.

Future studies should evaluate:

- SPF,
- UVA protection,
- UVB protection,
- photostability,
- cytotoxicity,
- formulation stability,

- skin permeation,
- and in-vivo photoprotection.

Wound-Healing Activity

Wound healing is a multifactorial process involving inflammation, fibroblast migration, extracellular matrix deposition, angiogenesis and re-epithelialization.

Sumalatha (2012) reported wound-healing activity of petroleum ether leaf extract using an excision wound model. More recent investigations have provided additional support.

Remya et al. (2022) reported antibacterial, antioxidant and wound-healing properties of C. infundibuliformis. The ethanolic extract demonstrated antibacterial activity, while a scratch assay suggested promotion of fibroblast migration.

These findings are pharmacologically interesting because antimicrobial activity combined with antioxidant and tissue-repair properties could provide a rational basis for topical applications.

Nanotechnology and Formulation Development

An important emerging area is incorporation of C. infundibuliformis extracts into advanced delivery systems.

Jyothi et al. (2017) developed a nanoparticulate hydrogel containing PLGA nanoparticles loaded with C. infundibuliformis leaf extract. The formulation was designed to improve sustained release and transdermal delivery.

The optimized formulation demonstrated prolonged drug release over approximately 24 hours and acceptable physicochemical characteristics, suggesting that nanotechnology may improve the pharmaceutical utility of plant extracts.

This approach may be particularly relevant for:

- wound-healing preparations,
- antimicrobial topical formulations,
- transdermal delivery,
- controlled release,
- improved stability,
- and enhanced skin permeation.

Green Synthesis of Copper Nanoparticles

Philip et al. (2025) investigated the green synthesis of copper nanoparticles using C. infundibuliformis leaf extract.

The synthesized nanoparticles were characterized using techniques including UV-visible spectroscopy, FTIR, SEM-EDX, TEM, XRD and zeta-potential analysis. Their antimicrobial, antioxidant, cytotoxicity and wound-healing properties were also evaluated.

This study illustrates a new direction in which C. infundibuliformis may function not only as a source of conventional phytochemicals but also as a biological reducing/capping system for nanomaterial synthesis.

Such approaches may lead to multifunctional biomaterials; however, nanoparticle-specific toxicity, dose optimization, long-term safety and environmental effects require careful investigation.

26. Anti-ulcer Potential

A recent 2026 study investigated the anti-ulcer potential of aerial parts of C. infundibuliformis using in-vitro acid-neutralization and H+/K+-ATPase inhibition assays.

The ethanolic extract demonstrated H+/K+-ATPase inhibition of approximately 71.76% at 500 µg/mL compared with 90.66% for omeprazole under the reported experimental conditions. The study also evaluated acid-neutralizing capacity (Hemadharsni et al., 2026).

This represents an emerging pharmacological area for the species. Nevertheless, in-vitro enzyme inhibition should be followed by validated in-vivo ulcer models such as:

- pylorus ligation,
- ethanol-induced ulcer,
- NSAID-induced ulcer,
- stress-induced ulcer,
- gastric mucus analysis,
- gastric acidity,
- pepsin activity,
- oxidative stress markers,
- and histopathology.

Summary of Pharmacological Activities

Table 2. Pharmacological activities reported for Crossandrainfundibuliformis

Activity	Plant part/extract	Experimental model	Major observation	Reference
Antioxidant	Leaves	DPPH/free-radical assays	Significant radical-scavenging activity	Sharmila & Gomathi, 2011
Antibacterial	Leaves	Agar diffusion	Activity against several bacteria	Madhumitha & Saral, 2011
Antifungal	Leaves	In-vitro assay	Antifungal activity	Madhumitha & Saral, 2011
Anticandidal	Leaves	In-vitro assay	Anticandidal activity	Madhumitha & Saral, 2011
Hepatoprotective	Leaves	CCl4-induced hepatic	Significant hepatoprotection	Madhumitha et al.,

Activity	Plant part/extract	Experimental model	Major observation	Reference
		injury		2010
Antidiabetic	Leaves/stems	Alloxan-induced diabetes	Reduced glucose and lipid parameters	Galanki et al., 2020
α-Amylase inhibition	Leaves	Enzyme assay	Concentration-dependent inhibition	Vadivel &Panwal, 2016
Anthelmintic	Leaves	Earthworm model	Concentration-dependent activity	Vadivel &Panwal, 2016
Anti-inflammatory	Flowers	Acute/chronic inflammation models	Anti-inflammatory effect	Dhamija et al., 2015
Analgesic	Leaves	Experimental pain models	Analgesic activity	Jayaveera et al., 2012
Anti-arthritic	Leaves	Protein-denaturation assay	Inhibition of protein denaturation	Sreevani et al.
Aphrodisiac	Leaves	Ethanol-induced testicular toxicity	Improved sexual behavior/testosterone	Kumar et al., 2010
Anticancer	Leaves	MCF-7 cells	Cytotoxicity	Vadivel &Panwal, 2016
Antimycobacterial	Leaves/flowers	M. tuberculosis assay	MIC reported	Satheesh Kumar et al., 2018
Anti-solar	Flowers	UV-visible assay	UV absorption	Vadlamudi et al., 2014
Wound healing	Leaves	Excision/scratch models	Improved wound-related parameters	Sumalatha, 2012; Remya et al., 2022
Larvicidal	Leaves	Mosquito larvae	Larvicidal activity	Madhumitha & Saral, 2012
Insecticidal	Leaves	S. oryzae	Dose-dependent insecticidal activity	Vadivel &Panwal, 2016
Anti-ulcer	Aerial parts	H+/K+-ATPase assay	Enzyme inhibition	Hemadharsni et al., 2026
Nanomedicine	Leaves	PLGA nanoparticulate hydrogel	Sustained release/transdermal potential	Jyothi et al., 2017
Nanoparticle synthesis	Leaves	Copper nanoparticles	Antimicrobial/antioxidant/wound activity	Philip et al., 2025

Possible Mechanistic Basis of Pharmacological Activities

The pharmacological effects of C. infundibuliformis may result from synergistic interactions among multiple secondary metabolites.

Flavonoids

Flavonoids may contribute to:

- antioxidant activity,
- inhibition of inflammatory mediators,
- membrane stabilization,
- antimicrobial effects,
- cytoprotection.

Phenolic compounds

Phenolics can act as free-radical scavengers and may contribute to antioxidant and antimicrobial effects.

Tannins

Tannins can interact with proteins and microbial cell surfaces and may contribute to antimicrobial, astringent and anthelmintic effects.

Saponins

Saponins may influence membrane permeability and have been associated with antimicrobial and other biological effects.

Terpenoids

Terpenoids represent a chemically diverse group with possible antioxidant, anti-inflammatory, antimicrobial and cytotoxic effects.

The exact contribution of each constituent, however, remains incompletely defined. Future bioactivity-guided fractionation should therefore be prioritized.

Safety and Toxicological Considerations

Despite extensive preliminary pharmacological research, systematic toxicological characterization of C. infundibuliformis remains comparatively limited.

Important parameters for future studies include:

- acute oral toxicity,
- repeated-dose toxicity,
- subchronic toxicity,
- genotoxicity,
- hepatotoxicity,
- nephrotoxicity,
- reproductive toxicity,
- hematological safety,
- biochemical safety,
- dermal irritation,
- dermal sensitization,
- and drug-herb interactions.

The 2026 aqueous-leaf-extract study reported hemolytic activity below 45% at the highest tested concentration, providing preliminary information about cytocompatibility but not a comprehensive safety assessment (Mulla et al., 2026).

Research Gaps

Although a broad spectrum of biological activities has been reported, several important gaps remain.

Limited compound-level evidence

Most investigations have used crude extracts rather than purified compounds. Therefore, the molecules responsible for the observed activities remain poorly characterized.

Lack of standardized extracts

Variability in plant genotype, geographic location, harvesting stage, drying conditions, extraction solvent and extraction procedure can significantly affect phytochemical composition.

Limited mechanistic studies

Many studies demonstrate activity but do not establish molecular mechanisms.

Limited in-vivo validation

Several reported activities are based only on in-vitro screening assays.

Limited clinical evidence

There is insufficient clinical evidence to establish therapeutic efficacy in humans.

Inadequate pharmacokinetic information

Absorption, distribution, metabolism, excretion and bioavailability of important constituents remain poorly understood.

Need for advanced analytical standardization

HPLC, HPTLC, LC-MS/MS, GC-MS and metabolomics should be used to develop chemical fingerprints and marker-based quality standards.

Need for modern pharmacological models

Mechanism-based investigations involving molecular pathways such as:

- Nrf2/HO-1,
- NF-κB,
- COX-2,
- TNF-α,
- IL-1β,
- IL-6,
- MAPK,
- PI3K/Akt,
- AMPK,
- and apoptotic pathways

could significantly strengthen the pharmacological evidence.

Future Research Perspectives

Future investigations should focus on converting preliminary observations into scientifically validated therapeutic applications.

Recommended research strategy

Step 1: Botanical authentication and cultivation standardization.
Step 2: Preparation of standardized extracts.
Step 3: HPTLC/HPLC/LC-MS/MS/GC-MS fingerprinting.
Step 4: Quantification of marker compounds.
Step 5: Bioactivity-guided fractionation.
Step 6: Isolation and structural characterization of active molecules.
Step 7: Mechanistic in-vitro investigations.
Step 8: Pharmacokinetic studies.
Step 9: Acute, subacute and chronic toxicity studies.
Step 10: Validated animal models.
Step 11: Development of suitable pharmaceutical formulations.
Step 12: Clinical evaluation where justified.

Particularly promising areas include **wound-healing formulations, antimicrobial preparations, hepatoprotective agents, antidiabetic formulations, anti-inflammatory preparations, natural sunscreen formulations and nanotechnology-based delivery systems**.

Potential Pharmaceutical Applications

Based on the existing literature, C. infundibuliformis could potentially be explored for:

1. Herbal antimicrobial formulations.
2. Wound-healing gels and creams.
3. Antioxidant formulations.
4. Natural sunscreen preparations.
5. Antidiabetic herbal preparations.
6. Hepatoprotective formulations.

7. Anti-inflammatory formulations.
8. Herbal oral-care products.
9. Nanoparticle-based antimicrobial systems.
10. Transdermal delivery systems.
11. Polyherbal formulations.
12. Standardized phytopharmaceutical preparations.

However, these applications should be regarded as **research and development possibilities rather than established clinical indications**.

2. CONCLUSION

Crossandrainfundibuliformis (L.) Nees is an important Acanthaceae species with dual horticultural and medicinal significance. Traditional applications of the plant have stimulated extensive preliminary pharmacological research. Experimental studies have demonstrated antioxidant, antibacterial, antifungal, anticandidal, hepatoprotective, antidiabetic, anti-inflammatory, analgesic, anti-arthritic, aphrodisiac, anticancer, anti-tubercular, anthelmintic, insecticidal, anti-solar and wound-healing activities.

The pharmacological potential appears to be associated with a diverse phytochemical profile comprising flavonoids, phenolics, tannins, alkaloids, saponins, terpenoids, steroids and glycosides. Recent investigations have further expanded the research landscape through GC–MS characterization, molecular docking, nanoparticulate hydrogel development and green synthesis of copper nanoparticles.

Despite these promising findings, the current evidence is predominantly preclinical. Major priorities include isolation and identification of active compounds, standardization of extracts, mechanism-based pharmacological studies, pharmacokinetic evaluation, comprehensive toxicity assessment and eventual clinical validation. Thus, C. infundibuliformis represents a scientifically interesting medicinal plant whose traditional importance can potentially be translated into standardized phytopharmaceutical and advanced drug-delivery applications through systematic future research.

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