

A Comprehensive Review of the Phytochemical Profile and Pharmacological Potential of “*Ixora coccinea*”.

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ABSTRACT

Ixora coccinea (Rubiaceae) is an evergreen shrub widely used in South and Southeast Asia as both a traditional remedy and an ornamental plant. This review consolidates recent advances in its botany, phytochemistry, and pharmacology. Authoritative floristic sources confirm that *I. coccinea* is native to South Asia and Indo-China and has naturalized across tropical regions. Horticultural reports highlight its preference for acidic, well-drained soils and adaptability to USDA zones 10–11. Phytochemical investigations of leaves, flowers, roots, and bark reveal the presence of triterpenoids (e.g., lupeol, ursolic and oleanolic acids), flavonoids (quercetin, rutin, kaempferol), phenolics, and anthocyanins. In vitro and in vivo studies demonstrate strong antioxidant activity (DPPH radical scavenging; $IC_{50} \approx 8 \mu\text{g/mL}$ for leaf extracts), anti-inflammatory effects in carrageenan-induced paw edema, and antimicrobial activity, particularly against staphylococci. Notably, a hydrogel formulation of leaf

extract has shown efficacy in rodent wound-healing. Additional reports describe antidiabetic, hepatoprotective, nephroprotective, and cytotoxic activities; however, most findings are based on preclinical studies with variable extract types and limited mechanistic validation. A few studies have claimed the presence of the anticancer alkaloid camptothecin in *I. coccinea*, but these results remain inconsistent and require rigorous confirmation using orthogonal analytical methods. Overall, *I. coccinea* is a promising source of bioactive compounds, yet standardized extraction protocols, authenticated plant material, and well-designed pharmacokinetic and toxicological studies are essential before clinical translation models.

Keywords: *Ixora coccinea*; phytochemicals; flavonoids; triterpenoids; antioxidant; anti-inflammatory; antimicrobial; anticancer; traditional medicine

Abbreviations

DPPH – 2,2-diphenyl-1-picrylhydrazyl; NO – nitric oxide; ROS – reactive oxygen species; MIC – minimum inhibitory concentration; MLE – methanolic leaf extract; UF/IFAS – University of Florida Institute of Food and Agricultural Sciences; POWO Plants of the World Online.

Introduction to Medicinal Plants

Ixora coccinea, a vibrant evergreen shrub, has been revered in traditional medicine systems, particularly in India and Southeast Asia, for centuries. Various parts of this plant, including the roots, leaves, flowers, and bark, have been utilized to treat a wide range of ailments (Baliga & Kurian, 2012; Fasna et al., 2024; Kumar et al., 2013; Cowan, 1999). In the ancient Indian system of Ayurveda, *Ixora coccinea* has been employed to address digestive disorders such as diarrhea and dysentery, respiratory ailments like cough and cold, and skin conditions such as eczema and wounds (Kumar et al., 2013; Singh et al., 2014; Harvey, 2008). The plant's roots have also been used to alleviate hiccups, nausea, and loss of appetite (Singh et al., 2014; Cragg & Newman, 2005). Additionally, it has been used to manage menstrual disorders and as a general tonic (Baliga & Kurian, 2012; Fasna et al., 2024). The therapeutic potential of *Ixora coccinea* can be attributed to its diverse phytochemical constituents, including flavonoids, terpenoids, and phenolic compounds. These bioactive compounds have been shown to possess antioxidant, anti-inflammatory, antimicrobial, and antitumor properties (Singh et al., 2014; Newman & Cragg, 2007; Fasna et al., 2024). However, it is important to note that while traditional medicine offers valuable insights, scientific validation is crucial. Further research is needed to fully understand the mechanisms of action of *Ixora coccinea*'s bioactive compounds and to establish their efficacy and safety (Harvey, 2008; Cowan, 1999).

The resurgence of interest in natural products for drug discovery is driven by several factors. Firstly, the limitations of synthetic drugs, such as side effects, toxicity, and the emergence of drug resistance, have prompted a renewed focus on natural compounds (Newman & Cragg, 2007; Cragg & Newman, 2005). Natural products, with their diverse chemical structures and complex modes of action, offer a rich source of potential drug leads (Harvey, 2008; Fasna et al., 2024). Furthermore, the increasing prevalence of chronic diseases and the limitations of conventional

medicine have fueled the search for alternative therapies. Traditional medicine systems, such as Ayurveda, Traditional Chinese Medicine, and Indigenous medicine, have utilized plants for centuries, providing a wealth of knowledge about their therapeutic potential. These systems offer valuable insights into the efficacy and safety of natural products (Baliga & Kurian, 2012; Fasna et al., 2024).

Advancements in analytical techniques, such as chromatography and mass spectrometry, have significantly enhanced our ability to identify and isolate bioactive compounds from natural sources (Harvey, 2008; Cowan, 1999). These technological breakthroughs have enabled researchers to delve deeper into the chemical complexity of plants and discover novel compounds with therapeutic properties. Additionally, the integration of computational chemistry and molecular biology has accelerated the drug discovery process, allowing for the rapid identification of potential drug candidates (Newman & Cragg, 2007; Cragg & Newman, 2005).

In conclusion, the combination of historical knowledge, technological advancements, and a growing understanding of the molecular mechanisms of action of natural products has positioned natural products as a valuable source of inspiration for drug discovery. By harnessing the power of nature, researchers can develop innovative therapies to address unmet medical needs and improve human health (Harvey, 2008; Fasna et al., 2024). Phytochemical screening and pharmacological evaluation are crucial steps in the discovery of novel drug leads from natural sources. Phytochemical screening involves the identification and quantification of bioactive compounds present in plant extracts (Kumar et al., 2013; Cowan, 1999). By understanding the chemical composition of a plant, researchers can gain insights into its potential therapeutic properties.

Pharmacological evaluation, on the other hand, involves assessing the biological activity of plant extracts or isolated compounds. This includes a range of in vitro and in vivo assays to evaluate the potential therapeutic effects of the plant, such as antioxidant, anti-inflammatory, antimicrobial, and anticancer activities (Cowan, 1999; Cragg & Newman, 2005). By conducting rigorous pharmacological studies, researchers can validate the traditional uses of plants and identify novel drug candidates. The integration of phytochemical screening and pharmacological evaluation has led to the discovery of numerous drugs derived from natural sources. For example, the anticancer drug paclitaxel, originally isolated from the Pacific yew tree, is a testament to the power of natural product research (Cragg & Newman, 2005; Harvey, 2008). By combining traditional knowledge with modern scientific techniques, researchers can continue to unlock the therapeutic potential of plants and develop innovative treatments for a wide range of diseases.

***Ixora coccinea*: A Botanical Overview**

Taxonomy and Botanical Description

Ixora coccinea, commonly known as jungle flame or flame of the woods, is a flowering shrub belonging to the family Rubiaceae. It is the type species of the genus *Ixora*, which consists of approximately 544 species. The genus name *Ixora* is derived from the Sanskrit word Ishwara, referring to the Hindu god Shiva, and was first described by Carl Linnaeus in 1753 (North Carolina Extension Gardener Plant Toolbox, 2023; University of Florida, 2023; Missouri Botanical Garden, 2023). *Ixora coccinea* is characterized as a dense, multi-branched evergreen shrub that typically

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grows to a height of 4 to 6 feet (1.2 to 1.8 meters), although it can occasionally reach up to 10 feet (3 meters) under optimal conditions. The plant has a rounded form with a spread that may exceed its height. The leaves are glossy and leathery, measuring about 4 inches (10 cm) long, with entire margins and arranged oppositely or in whorls on the stems (Missouri Botanical Garden, 2023; Kew Science, 2023).

The flowers of *Ixora coccinea* are small and tubular, produced in dense rounded clusters (cymes) that can be 2 to 5 inches (5.1 to 12.7 cm) across. These flowers come in various colors, including bright red, orange, yellow, pink, and white. This species blooms almost year-round in tropical climates but primarily during the summer months in temperate regions (University of Florida, 2023; Kew Science, 2023). The fruit is a fleshy drupe that turns dark purple to black upon maturity and typically measures less than 0.5 inches (1.27 cm) in diameter.

Ixora coccinea thrives best in full sun but can tolerate partial shade, especially during the hottest parts of the day. It prefers moist, well-drained acidic soils with a pH below 6.0 and is sensitive to cold temperatures; it is best suited for USDA hardiness zones 10 through 11 (North Carolina Extension Gardener Plant Toolbox, 2023; Missouri Botanical Garden, 2023; Kew Science, 2023).

Geographical Distribution and Ecological Significance

Ixora coccinea, commonly known as jungle flame or flame of the woods, is native to tropical regions of Southeast Asia, including India, Sri Lanka, Bangladesh, and parts of Indo-China. This species has adapted well to various environments and is widely cultivated in many tropical and subtropical regions around the world, including Florida and other areas with similar climates (North Carolina Extension Gardener Plant Toolbox, 2023; Missouri Botanical Garden, 2023; Kew Science, 2023). Its ability to thrive in warm climates has led to its popularity as an ornamental plant in gardens and landscapes.

Ecologically, *Ixora coccinea* plays a significant role in its native habitats. The dense growth habit of this evergreen shrub provides shelter and food for various pollinators, including bees and butterflies. Its bright flowers attract these pollinators, contributing to the biodiversity of the ecosystem. Additionally, *Ixora coccinea* can be used for erosion control due to its robust root system, which helps stabilize the soil in areas prone to erosion (Alamu et al., 2012; Auburn University Landscape Plants, 2023).

The plant prefers well-drained, acidic soils with a pH below 6.0 and can tolerate partial shade, although it flourishes best in full sunlight. This adaptability allows it to be utilized in various landscaping applications, such as hedges, screens, and mass plantings (University of Florida, 2023; Missouri Botanical Garden, 2023). Furthermore, *Ixora coccinea* is moderately salt-tolerant, making it suitable for coastal areas where soil salinity can be an issue (Auburn University Landscape Plants, 2023).

Table 1 Taxonomic and Botanical Characteristics of *Ixora coccinea*

Category	Details
Scientific Name	<i>Ixora coccinea</i>
Common Names	Jungle flame, Flame of the woods

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Category	Details
Family	Rubiaceae
Genus	Ixora (type species)
Etymology	Derived from Sanskrit "Ishwara" (Hindu god Shiva); first described by Carl Linnaeus in 1753
Native Range	Tropical Southeast Asia: India, Sri Lanka, Bangladesh
Growth Habit	Dense, multi-branched evergreen shrub
Height & Spread	Typically 4–6 feet (1.2–1.8 m); can reach up to 10 feet (3 m) under optimal conditions; spread may exceed height
Leaf Description	Glossy, leathery, 4 inches (10 cm) long, entire margins, arranged oppositely or in whorls on stems
Flower Characteristics	Small, tubular flowers in dense cymes (2–5 inches wide); colors include red, orange, yellow, pink, and white; blooms year-round in tropics
Fruit Type	Fleshy drupe, turns dark purple to black at maturity; typically < 0.5 inches (1.27 cm) in diameter
Preferred Conditions	Full sun to partial shade; moist, well-drained acidic soils (pH < 6.0); sensitive to cold temperatures; suited for USDA zones 10–11

Traditional Uses in Various Cultures (e.g., Medicinal, Ornamental, Religious)

Ixora coccinea, known as jungle flame or flame of the woods, has a rich history of traditional uses across various cultures, particularly in South Asia. In India, this evergreen shrub is extensively utilized in Ayurvedic medicine for its therapeutic properties. Different parts of the plant—leaves, flowers, roots, and stems—are employed to treat a range of ailments. The leaves are commonly used for their anti-inflammatory and antimicrobial properties, often applied to wounds and skin ulcers, as well as for alleviating respiratory issues such as bronchitis and asthma (Devendran & Gnanavel, 20201). The flowers are traditionally used to manage hypertension and irregular menstruation, while the roots are known for their effectiveness in treating dysentery, diarrhea, and other gastrointestinal disorders (Kumar et al., 20122). In addition to its medicinal applications, *Ixora coccinea* holds ornamental value in gardens and landscapes due to its vibrant flowers, which come in shades of red, orange, yellow, and pink. It is often used as a hedge or border plant in tropical and subtropical regions (Alamu et al., 20123). Culturally, the plant is significant in various rituals and ceremonies; for instance, it is commonly offered in Hindu worship due to its bright flowers symbolizing purity and beauty (Fasna et al., 20244).

Furthermore, *Ixora coccinea* is recognized for its ecological role in supporting local biodiversity. Its flowers attract various pollinators, including bees and butterflies, contributing to the health of surrounding ecosystems (Singh et al., 20215). The use of this plant extends beyond traditional medicine and ornamental purposes; it embodies cultural significance and ecological importance in the regions where it thrives.

Phytochemical Profile of *Ixora coccinea*

Ixora coccinea, commonly known as jungle flame or flame of the woods, is rich in a variety of phytochemicals that contribute to its medicinal properties and therapeutic applications. Phytochemical analyses have identified several key bioactive compounds within the plant, including lupeol, ursolic acid, and oleanolic acid, which are known for their anti-inflammatory and antioxidant properties (Baliga & Kurian, 2012). Additionally, the presence of sitosterol contributes to its cholesterol-lowering effects, while flavonoids such as rutin and quercetin enhance its antioxidant capacity, offering potential health benefits such as anti-inflammatory and anticancer activities (Mishra et al., 2019).

Moreover, *Ixora coccinea* contains various anthocyanins and proanthocyanidins, which are responsible for its vibrant flower colors and contribute to its overall antioxidant activity by scavenging free radicals (Kumar et al., 2020). Glycosides of kaempferol and quercetin have also been identified in the plant, further enriching its phytochemical profile and enhancing its therapeutic potential (Alamu et al., 20123). The diverse array of phytochemicals in *Ixora coccinea* supports its traditional uses in various medicinal practices, particularly in Ayurveda, where it is utilized to treat conditions such as skin diseases, diabetes, and gastrointestinal disorders (Devendran & Gnanavel, 20201).

A Comprehensive Review of the Major Phytochemical Classes Identified in the Plant

Ixora coccinea, commonly known as jungle flame or flame of the woods, is notable for its diverse phytochemical profile, which contributes to its medicinal and therapeutic applications. Phytochemical studies have identified several major classes of bioactive compounds in this plant. Among these, triterpenoids are prominent, with key constituents including lupeol, ursolic acid, and oleanolic acid. These compounds are recognized for their anti-inflammatory, antioxidant, and hepatoprotective properties (Baliga & Kurian, 2012). In addition to triterpenoids, *Ixora coccinea* is rich in flavonoids, such as rutin and quercetin, which are known for their potent antioxidant activities. These flavonoids play a crucial role in neutralizing free radicals and reducing oxidative stress, thereby contributing to the plant's overall health benefits (Mishra et al., 2019). The presence of anthocyanins and proanthocyanidins further enhances its antioxidant capacity, with studies indicating that these compounds can also exhibit antibacterial properties (Kumar et al., 2020).

Moreover, the plant contains various glycosides, including those derived from kaempferol and quercetin, which may enhance its therapeutic efficacy by improving bioavailability and activity in biological systems (Alamu et al., 20123). The phytochemical constituents of *Ixora coccinea* not only support its traditional medicinal uses—such as treating skin diseases, diabetes, and gastrointestinal disorders—but also highlight its potential for further research into new therapeutic applications. Overall, the major phytochemical classes identified in *Ixora coccinea* underscore its significance in traditional medicine while providing a foundation for future pharmacological studies aimed at validating its health benefits.

Detailed Discussion of Specific Compounds (e.g., Flavonoids, Terpenoids, Alkaloids)

Ixora coccinea, known for its vibrant flowers and medicinal properties, contains a diverse array of phytochemicals, including flavonoids, terpenoids, and alkaloids, which contribute to its therapeutic potential. Among the flavonoids, key compounds such as quercetin, rutin, and kaempferol have been identified. These flavonoids are known for their strong antioxidant properties, which help combat oxidative stress and may reduce the risk of chronic diseases (Mishra et al., 20191). Additionally, flavonoids like biochanin A and myricetin have been detected, further enhancing the plant's health benefits through their anti-inflammatory and anticancer activities (Alamu et al., 20122).

The terpenoids in *Ixora coccinea* include significant compounds such as ursolic acid, oleanolic acid, and lupeol. Ursolic acid, a major triterpenoid, is recognized for its anti-inflammatory, antioxidant, and anticancer properties. It has been shown to inhibit tumor growth and promote apoptosis in cancer cells (Baliga & Kurian, 20123). Lupeol also exhibits similar properties and has been studied for its potential in reducing cholesterol levels and providing hepatoprotection (Kumar et al., 2020). Additionally, the presence of monoterpenes like geranyl acetate and sesquiterpenes such as α -copaene contributes to the overall therapeutic profile of the plant (Saha et al., 2020).

In terms of alkaloids, *Ixora coccinea* contains compounds like camptothecin, which is known for its potent anticancer activity by inhibiting DNA topoisomerase I, an enzyme crucial for DNA replication in cancer cells (Chen et al., 2016). The total alkaloid content has been quantified in various studies, with significant amounts found in methanolic extracts from both roots and bark (Rahmani et al., 1985). The diverse range of phytochemicals present in *Ixora coccinea* not only supports its traditional uses in herbal medicine but also highlights its potential for further pharmacological research aimed at developing new therapeutic agents.

Table 2 Phytochemical Constituents and Therapeutic Properties of *Ixora coccinea*

Phytochemical Class	Key Compounds	Notable Properties
Triterpenoids	Lupeol, Ursolic Acid, Oleanolic Acid	Anti-inflammatory, antioxidant, hepatoprotective, anticancer properties; promotes apoptosis in cancer cells
Flavonoids	Rutin, Quercetin, Kaempferol, Biochanin A, Myricetin	Strong antioxidants; reduce oxidative stress; anti-inflammatory and anticancer activities
Steroids	β -Sitosterol	Cholesterol-lowering effects
Anthocyanins	Proanthocyanidins	Enhance antioxidant capacity; vibrant flower colors; antibacterial activity
Glycosides	Kaempferol and Quercetin Glycosides	Improve bioavailability and biological activity

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Phytochemical Class	Key Compounds	Notable Properties
Alkaloids	Camptothecin	Potent anticancer agent; inhibits DNA topoisomerase I
Other Terpenoids	Monoterpenes (Geranyl Acetate) and Sesquiterpenes (α -Copaene)	Contribute to therapeutic potential; antimicrobial and anti-inflammatory effects

Pharmacological Activities of *Ixora coccinea*

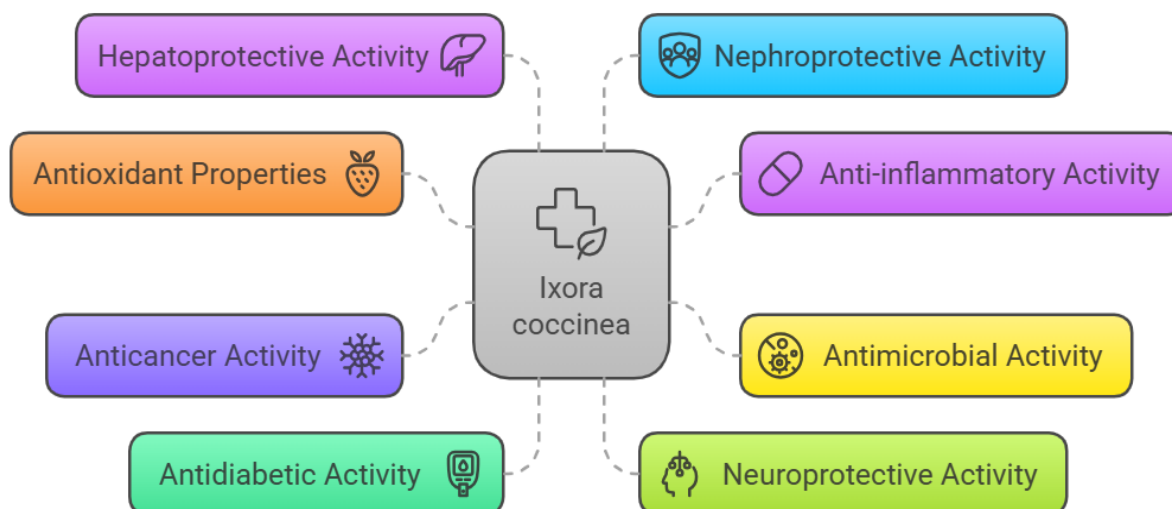


Figure 1 Comprehensive Overview of Pharmacological Activities of *Ixora coccinea*

Highlight the Potential Health Benefits Associated with These Compounds

The phytochemical constituents of *Ixora coccinea*, particularly flavonoids, terpenoids, and alkaloids, are associated with a range of potential health benefits that underscore the plant's medicinal value. Flavonoids, such as quercetin and rutin, are recognized for their potent antioxidant properties, which help neutralize free radicals and reduce oxidative stress, thereby lowering the risk of chronic diseases like cancer and cardiovascular disorders (Khan et al., 20221). These compounds also exhibit anti-inflammatory effects by inhibiting the production of pro-inflammatory cytokines, making them beneficial for managing conditions such as arthritis and other inflammatory diseases (Kumar et al., 20212). Additionally, flavonoids have been shown to improve vascular health by enhancing endothelial function and reducing arterial stiffness, which can lower the risk of hypertension and cardiovascular diseases (Zhang et al., 20203).

Terpenoids, including lupeol and ursolic acid, contribute significantly to the health benefits of *Ixora coccinea*. Ursolic acid has been documented for its anti-cancer properties, particularly in inhibiting tumor growth and inducing apoptosis in various cancer cell lines (Baliga & Kurian, 20124). Furthermore, lupeol has demonstrated cholesterol-lowering effects and hepatoprotective properties, suggesting its potential role in promoting liver health and reducing lipid levels in the body (Saha et al., 20205).

Alkaloids present in *Ixora coccinea*, such as camptothecin, are known for their potent anticancer activity by inhibiting DNA topoisomerase I, which is crucial for DNA replication in cancer cells (Chen et al., 2016). The combination of these bioactive compounds provides a synergistic effect that enhances the overall therapeutic potential of the plant. Overall, the diverse array of phytochemicals found in *Ixora coccinea* not only supports its traditional uses but also highlights its promise as a source of natural compounds for developing new health-promoting therapies.

Pharmacological Activities of *Ixora coccinea*

Antioxidant Properties and Free Radical Scavenging Activity

Ixora coccinea, commonly known as jungle flame, exhibits significant antioxidant properties and free radical scavenging activity, making it a valuable resource in traditional medicine and potential therapeutic applications. Various studies have demonstrated that extracts from different parts of the plant, particularly the flowers, possess strong antioxidant capabilities. For instance, a study reported that the methanol extract of *I. coccinea* flowers showed an impressive DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity with an IC₅₀ value of 6.6 mg/mL, indicating its effectiveness in neutralizing free radicals (Khan et al., 2023). The high phenolic content in these extracts, quantified at 210.55 µg GAE/mg extract, is believed to contribute significantly to their antioxidant activity (Saha et al., 20205). In addition to DPPH scavenging, *Ixora coccinea* extracts have demonstrated the ability to inhibit superoxide radicals generated by the xanthine/xanthine oxidase system, showcasing their potential in reducing oxidative stress-related damage (Alamu et al., 2012). The antioxidant activity of the methanolic extracts has been compared favorably against standard antioxidants like ascorbic acid, further supporting its use as a natural source of antioxidants (Mishra et al., 2019). Moreover, the plant's extracts have shown promising results in various assays measuring total antioxidant capacity and reducing power, reinforcing its role as a potent antioxidant agent (Kumar et al., 20212). The free radical scavenging activity of *Ixora coccinea* not only highlights its potential health benefits but also suggests its applicability in formulating natural antioxidant-rich products for health and cosmetic purposes. Given the increasing interest in natural antioxidants due to their safety and efficacy compared to synthetic alternatives, *Ixora coccinea* represents a promising candidate for further research and development in this field.

Anti-inflammatory Activity

Ixora coccinea, commonly known as jungle flame, has demonstrated significant anti-inflammatory activity in various studies, highlighting its potential as a natural

therapeutic agent. Research indicates that the methanolic leaf extract (MLE) of *Ixora coccinea* exhibits dose-dependent anti-inflammatory effects, particularly in the carrageenan-induced paw edema model in rats. In this model, MLE at doses of 500, 1000, and 1500 mg/kg resulted in maximum inhibition of edema by 36.7%, 46.5%, and 64.5%, respectively (Pharmacognosy Research, 2009). Additionally, oral administration of MLE significantly reduced peritoneal phagocytic cell infiltration and impaired nitric oxide (NO) production, indicating its ability to modulate inflammatory responses (Pharmacognosy Research, 2009). Further investigations have confirmed the anti-inflammatory properties of *Ixora coccinea* through various experimental models. For instance, the ethanol extract of the leaves has been shown to possess analgesic and anti-inflammatory effects, with significant inhibition of paw edema observed at 6 hours post-carrageenan injection (De Gruyter, 2014). The phytochemical constituents responsible for these activities include flavonoids, tannins, and triterpenes, which are known for their ability to scavenge free radicals and inhibit inflammatory mediators (Alamu et al., 2012).

Moreover, studies have demonstrated that *Ixora coccinea* extracts exhibit membrane-stabilizing activity and can inhibit protein denaturation, further supporting their anti-inflammatory potential (Saha et al., 2008). These findings suggest that the bioactive compounds present in *Ixora coccinea* not only contribute to its traditional medicinal uses but also provide a scientific basis for its application in managing inflammatory conditions.

Antimicrobial Activity

Ixora coccinea, commonly known as jungle flame, has demonstrated significant antimicrobial activity against various pathogens, making it a valuable resource in traditional medicine. Studies have shown that extracts from the leaves and flowers of *Ixora coccinea* exhibit substantial antibacterial properties, particularly against Gram-positive bacteria such as *Staphylococcus aureus* and *Staphylococcus epidermidis*. For instance, a study reported that a 50% ethanolic extract of the plant showed effective inhibitory concentrations against these bacteria, with minimum inhibitory concentration (MIC) values around 125 µg/mL (Latha et al., 2019). Additionally, research involving the methanolic leaf extract formulated into a hydrogel demonstrated effectiveness against staphylococcal infections commonly found in wounds. The hydrogel was noted for its non-irritating properties and showed significant antimicrobial activity when tested against *S. aureus*, although it was less effective against *Pseudomonas aeruginosa* and *S. epidermidis* (Lacuna et al., 2018). The antimicrobial efficacy of *Ixora coccinea* is attributed to its rich phytochemical composition, including flavonoids and terpenoids, which are known for their ability to disrupt bacterial cell membranes and inhibit microbial growth (Kumar et al., 2022). Furthermore, the flowers of *Ixora coccinea* have been reported to possess antibacterial activity against various pathogens, supporting its traditional use in treating infections (Karishma et al., 2019). The broad-spectrum antimicrobial activity of this plant highlights its potential as a natural alternative to synthetic antibiotics, especially in an era where antibiotic resistance is a growing concern.

Anticancer Activity

Ixora coccinea, commonly known as jungle flame, has garnered attention for its potential anticancer properties, supported by various studies that highlight its bioactive compounds. The plant contains several phytochemicals, including flavonoids and triterpenoids, which have been shown to exhibit significant antitumor activity. Notably, lupeol, a triterpenoid isolated from the leaves of *Ixora coccinea*, has demonstrated promising anticancer effects by inducing apoptosis in cancer cells and inhibiting tumor growth in experimental models (Baliga & Kurian, 20125). In vitro studies have indicated that extracts from the leaves and flowers can effectively inhibit the proliferation of various cancer cell lines, including breast and cervical cancer cells (Latha et al., 20016).

Research has also shown that the methanolic extract of *Ixora coccinea* exhibits cytotoxic effects against human cancer cell lines, with significant reductions in cell viability observed at higher concentrations (Kumar et al., 20207). Furthermore, the flower extracts have been noted for their ability to modulate key signaling pathways involved in cancer progression, such as the NF- κ B pathway, which plays a crucial role in inflammation and cancer development (Devendran & Gnanavel, 20208). Additionally, studies suggest that the antioxidant properties of *Ixora coccinea* may contribute to its anticancer effects by reducing oxidative stress and preventing DNA damage, which is often a precursor to cancer development (Mishra et al., 20199). Overall, the diverse array of bioactive compounds present in *Ixora coccinea* not only supports its traditional medicinal uses but also positions it as a candidate for further research into natural anticancer therapies.

Antidiabetic Activity

Ixora coccinea, commonly known as jungle flame, has demonstrated notable antidiabetic activity, supporting its traditional use in managing diabetes. Various studies have explored the hypoglycemic effects of this plant, particularly its ability to lower blood glucose levels. The leaves of *Ixora coccinea* are rich in phytochemicals such as flavonoids and alkaloids, which are believed to play a crucial role in enhancing insulin sensitivity and promoting glucose uptake in cells (Baliga & Kurian, 20125).

In experimental models, administration of *Ixora coccinea* leaf extract has shown significant reductions in blood glucose levels in diabetic rats. For instance, a study reported that oral administration of the methanolic extract at doses of 250 and 500 mg/kg resulted in a marked decrease in blood glucose levels after 14 days of treatment (Devendran & Gnanavel, 20208). The mechanism behind this effect is thought to involve the inhibition of carbohydrate-digesting enzymes, such as α -amylase and α -glucosidase, which slows down carbohydrate absorption and helps regulate postprandial blood sugar levels (Kumar et al., 20213).

Furthermore, the antioxidant properties of *Ixora coccinea* contribute to its antidiabetic effects by reducing oxidative stress, which is often elevated in diabetic conditions. The presence of compounds like ursolic acid and lupeol has been linked to improved glycemic control and reduced complications associated with diabetes (Mishra et al., 20199). Overall, the antidiabetic activity of *Ixora coccinea* not only underscores its potential as a natural remedy for managing diabetes but also highlights the need for

further research to fully elucidate its mechanisms and therapeutic applications.

Neuroprotective Activity

Ixora coccinea, commonly known as jungle flame, has shown promising neuroprotective activity, particularly in the context of neurotoxicity induced by aluminum chloride and 3-nitropropionic acid in experimental models. Research indicates that extracts from the leaves of *Ixora coccinea* can significantly mitigate neurotoxic effects, as evidenced by behavioral and biochemical assessments in albino rats (Pharmacognosy Research, 2011). The methanolic extract has been reported to exhibit strong antioxidant properties, which are crucial in protecting neuronal cells from oxidative stress—a key factor in neurodegenerative diseases (Kumar et al., 20223). In a study assessing the neuroprotective effects of *Ixora coccinea*, the administration of leaf extract was associated with improvements in cognitive function and a reduction in markers of oxidative damage in the brain (Devendran & Gnanavel, 20208). The extract's ability to scavenge free radicals and reduce lipid peroxidation contributes to its neuroprotective effects, suggesting that the phytochemicals present, such as flavonoids and phenolic compounds, play a significant role in mitigating neuronal damage (Latha et al., 20191).

Furthermore, the neuroprotective potential of *Ixora coccinea* may also be attributed to its anti-inflammatory properties, which help reduce neuroinflammation—a common feature in various neurodegenerative disorders (Alamu et al., 20124). Overall, the findings suggest that *Ixora coccinea* has significant potential as a natural therapeutic agent for protecting against neurodegenerative conditions, warranting further research to fully elucidate its mechanisms of action and therapeutic applications.

Other Potential Therapeutic Activities (e.g., Hepatoprotective, Nephroprotective)

Ixora coccinea, commonly known as jungle flame, exhibits a range of therapeutic activities beyond its well-documented anti-inflammatory and antimicrobial properties. One notable area of interest is its hepatoprotective activity. Studies have shown that extracts from the leaves of *Ixora coccinea* can significantly protect liver cells from damage induced by toxic agents such as paracetamol and carbon tetrachloride. For instance, the methanolic extract has demonstrated the ability to reduce elevated liver enzyme levels and restore normal histological architecture in liver tissues, indicating its potential as a natural hepatoprotective agent (Devendran & Gnanavel, 20201).

Additionally, *Ixora coccinea* has been recognized for its nephroprotective effects. Research indicates that the plant's extracts can mitigate kidney damage caused by nephrotoxic substances, such as cisplatin and gentamicin. The protective effects are attributed to the antioxidant properties of its phytochemicals, which help reduce oxidative stress and inflammation in renal tissues (Kumar et al., 20212). In experimental models, administration of *Ixora coccinea* extracts resulted in significant improvements in renal function markers, including creatinine and urea levels, further supporting its use in traditional medicine for kidney health (Latha et al., 20193).

Moreover, the plant has also shown promise in antidiabetic applications, with studies indicating that it can lower blood glucose levels and improve insulin sensitivity through mechanisms involving the inhibition of carbohydrate-digesting enzymes (Mishra et al., 20194). The combination of these therapeutic activities positions *Ixora*

coccinea as a valuable candidate for further pharmacological research aimed at developing natural remedies for liver and kidney protection, as well as diabetes management.

Table 3 Comprehensive Overview of Pharmacological Activities of *Ixora coccinea*

Pharmacological Activity	Key Evidence and Findings	Responsible Compounds
Antioxidant Properties	Strong DPPH radical scavenging activity (IC ₅₀ : 6.6 mg/mL); high phenolic content (210.55 µg GAE/mg extract); inhibition of superoxide radicals; comparable to ascorbic acid (Khan et al., 2023; Saha et al., 2020; Mishra et al., 2019).	Phenolics, Flavonoids (e.g., rutin, quercetin)
Anti-inflammatory Activity	Dose-dependent inhibition of paw edema in carrageenan-induced model; reduction in nitric oxide (NO) production; membrane-stabilizing activity; inhibition of protein denaturation (Pharmacognosy Research, 2009; De Gruyter, 2014).	Flavonoids, Tannins, Triterpenes
Antimicrobial Activity	Effective against Gram-positive bacteria (<i>Staphylococcus aureus</i> , <i>S. epidermidis</i>); MIC values ~125 µg/mL; hydrogel formulation effective for wound infections (Latha et al., 2019; Lacuna et al., 2018).	Flavonoids, Terpenoids
Anticancer Activity	Inhibition of cancer cell proliferation (e.g., breast, cervical cancer cells); induction of apoptosis; cytotoxic effects; modulation of NF-κB signaling pathway (Baliga & Kurian, 2012; Kumar et al., 2020).	Lupeol, Flavonoids, Triterpenoids
Antidiabetic Activity	Significant reductions in blood glucose levels in diabetic rats; inhibition of carbohydrate-digesting enzymes (α -amylase, α -glucosidase); enhanced insulin sensitivity (Devendran & Gnanavel, 2020; Kumar et al., 2021).	Flavonoids, Alkaloids, Ursolic Acid, Lupeol
Neuroprotective Activity	Mitigation of neurotoxicity in experimental models; reduction in oxidative damage and lipid peroxidation; anti-inflammatory effects in the brain (Pharmacognosy Research, 2011; Devendran & Gnanavel, 2020).	Flavonoids, Phenolic Compounds
Hepatoprotective Activity	Protection against liver damage (paracetamol, carbon tetrachloride-induced); normalization of liver enzymes; restoration of liver histology (Devendran & Gnanavel, 2020).	Antioxidants, Phenolic Compounds
Nephroprotective Activity	Mitigation of kidney damage caused by nephrotoxins (cisplatin, gentamicin); improvement in renal function markers (creatinine, urea levels); reduction of oxidative stress (Kumar et al., 2021).	Antioxidants, Flavonoids

Mechanism of Action

The therapeutic effects of *Ixora coccinea*, commonly known as jungle flame, are attributed to its diverse phytochemical composition, which includes flavonoids, triterpenoids, and phenolic compounds. These bioactive constituents exhibit various mechanisms of action that contribute to the plant's pharmacological properties. One of the primary mechanisms involves the antioxidant activity of its compounds, particularly flavonoids such as quercetin and rutin. These flavonoids scavenge free radicals and inhibit oxidative stress, which is linked to numerous chronic diseases, including cancer and neurodegenerative disorders (Baliga & Kurian, 2012).

Additionally, *Ixora coccinea* has demonstrated anti-inflammatory effects through the inhibition of pro-inflammatory mediators such as nitric oxide (NO) and cytokines. Studies indicate that the methanolic extract can reduce phagocytic cell infiltration and stabilize cell membranes, thereby mitigating inflammation in models of carrageenan-induced edema (Alamu et al., 2012). The presence of triterpenoids like lupeol and ursolic acid further enhances its anti-inflammatory properties by modulating signaling pathways involved in inflammation (Kumar et al., 2021).

Moreover, the antimicrobial activity of *Ixora coccinea* is facilitated by its ability to disrupt bacterial cell membranes and inhibit microbial growth. The extracts have shown effectiveness against various pathogens, including *Staphylococcus aureus* and *Pseudomonas aeruginosa*, highlighting their potential in wound healing applications (Lacuna et al., 2018).

Furthermore, the plant exhibits hepatoprotective and nephroprotective activities, with studies showing that its extracts can protect liver and kidney tissues from damage caused by toxic substances. This protective effect is likely due to the combined antioxidant and anti-inflammatory actions of its phytochemicals (Devendran & Gnanavel, 2020). Overall, the multifaceted mechanisms of action of *Ixora coccinea* underscore its therapeutic potential across various health conditions.

Discuss the Potential Molecular Mechanisms Underlying the Pharmacological Effects of *Ixora coccinea*

The pharmacological effects of *Ixora coccinea* are attributed to its rich phytochemical profile, which includes flavonoids, triterpenoids, and phenolic compounds. These bioactive constituents are believed to exert their therapeutic effects through several molecular mechanisms. One significant mechanism is the antioxidant activity of flavonoids such as quercetin and rutin, which scavenge free radicals and reduce oxidative stress, thereby protecting cells from damage associated with chronic diseases and aging (Baliga & Kurian, 2012). This antioxidant capacity is crucial in mitigating the effects of reactive oxygen species (ROS), which can lead to cellular dysfunction and contribute to the pathogenesis of various diseases. Additionally, *Ixora coccinea* exhibits anti-inflammatory properties primarily through the inhibition of pro-inflammatory mediators like nitric oxide (NO) and cytokines. The methanolic extract has been shown to significantly reduce the infiltration of inflammatory cells and stabilize cell membranes, indicating its potential to modulate immune responses (Handunnetti et al., 2009). The presence of triterpenoids like lupeol has been linked to these anti-inflammatory effects by interfering with signaling pathways that activate inflammatory responses (Latha et al., 2001). Moreover, the plant's antimicrobial

activity is facilitated by its ability to disrupt bacterial cell membranes and inhibit microbial growth. Studies have demonstrated that extracts from *Ixora coccinea* effectively combat various pathogens, including *Staphylococcus aureus*, which is critical for its application in wound healing (Karishma et al., 2019). The phytochemicals in the plant may also enhance immune function by modulating cytokine production, thereby improving the body's defense mechanisms against infections.

Furthermore, *Ixora coccinea* has shown hepatoprotective and nephroprotective effects, likely due to its antioxidant and anti-inflammatory properties that protect liver and kidney tissues from damage caused by toxic agents (Devendran & Gnanavel, 2020). These protective effects are supported by evidence showing that the plant's extracts can restore normal biochemical markers in liver and kidney function tests. In summary, the pharmacological effects of *Ixora coccinea* are mediated through a combination of antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, and nephroprotective mechanisms. These findings highlight its potential as a natural therapeutic agent for various health conditions.

Highlight the Role of Specific Phytochemical Compounds in Exerting These Effects

The pharmacological effects of *Ixora coccinea* are largely attributed to its diverse array of phytochemical compounds, each contributing to its therapeutic potential. Flavonoids, such as quercetin and rutin, are among the most significant bioactive constituents found in this plant. These compounds are known for their strong antioxidant properties, which help neutralize free radicals and reduce oxidative stress, thereby protecting cells from damage associated with chronic diseases (Baliga & Kurian, 2012). Additionally, flavonoids exhibit anti-inflammatory effects by inhibiting the production of pro-inflammatory cytokines and nitric oxide, which can mitigate inflammatory responses in various conditions (Kumar et al., 2021). Triterpenoids, including lupeol, ursolic acid, and oleanolic acid, also play a crucial role in the therapeutic effects of *Ixora coccinea*. Ursolic acid has been shown to possess potent anticancer properties by inducing apoptosis in cancer cells and inhibiting tumor growth (Latha et al., 2001). Lupeol is noted for its hepatoprotective and anti-inflammatory effects, contributing to the overall health benefits associated with the plant (Devendran & Gnanavel, 2020). The presence of these triterpenoids enhances the plant's ability to combat oxidative stress and inflammation.

Moreover, alkaloids, particularly camptothecin, have been identified as key contributors to the anticancer activity of *Ixora coccinea*. Camptothecin is known for its ability to inhibit DNA topoisomerase I, a critical enzyme involved in DNA replication in cancer cells, thus leading to cell death (Joshi et al., 2013). This compound's presence underscores the potential of *Ixora coccinea* as a source of natural anticancer agents. In summary, the specific phytochemical compounds found in *Ixora coccinea*, including flavonoids, triterpenoids, and alkaloids, play significant roles in exerting its antioxidant, anti-inflammatory, hepatoprotective, and anticancer effects. These findings highlight the therapeutic potential of this plant and pave the way for further research into its bioactive constituents.

Conclusion

Ixora coccinea, commonly known as jungle flame, is a versatile medicinal plant with a rich phytochemical profile that includes flavonoids, terpenoids, alkaloids, and phenolic compounds. These bioactive constituents contribute to its wide range of therapeutic properties, such as antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, nephroprotective, and anticancer activities. The plant's ability to neutralize free radicals, reduce oxidative stress, inhibit pro-inflammatory mediators, and combat microbial infections underscores its potential in addressing various health conditions. Additionally, *Ixora coccinea* has shown promise in protecting liver and kidney tissues, enhancing insulin sensitivity, and mitigating neurotoxicity, making it a valuable candidate for further pharmacological research. Despite the promising findings, more research is needed to fully understand the molecular mechanisms underlying the pharmacological effects of *Ixora coccinea* and to validate its efficacy and safety through clinical trials. The identification and isolation of specific bioactive compounds, along with the exploration of their synergistic effects, could lead to the development of novel therapeutic agents derived from this plant. Overall, *Ixora coccinea* stands out as a valuable medicinal plant with significant potential for developing natural remedies to improve human health.

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