

# A Review of Vulnerary Application of Selected Medicinal Plants in Traditional Health Care

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## ABSTRACT

Wound healing and inflammation are highly intricate biological processes that work to restore the body's tissue structure and function after injury. In recent years, growing interest has focused on plant-based bioactive compounds as promising therapeutic options, largely because of their proven effectiveness, safety, and low risk of side effects. A wide range of phytochemicals-such as flavonoids, alkaloids, tannins, saponins, terpenoids, and phenolic compounds-have shown strong wound-healing and anti-inflammatory potential. These natural compounds exert their effects through various mechanisms, including antioxidant defense, regulation of cytokine activity, stimulation of collagen formation, promotion of new blood vessel growth, and suppression of inflammatory mediators like prostaglandins and nitric oxide. By combining traditional herbal knowledge with modern pharmacological research, scientists have been able to validate and better understand the therapeutic roles of many medicinal plants in treating wounds and inflammation. This review seeks to explore and critically assess how plant-derived constituents contribute to tissue repair and inflammation control, outlining their underlying mechanisms, therapeutic potential, and future directions for developing innovative plant-based pharmaceuticals.

**Keywords:** Angiogenesis stimulation, Cytokines modulation, Herbal drugs, Oxidative Stress control, Tissue repair promotion, Wound healing.

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## INTRODUCTION

Wound healing is a complex and dynamic physiology process that restores the structural and functional integrity of damaged tissues. It proceeds through series of events such as hemostasis, inflammation, proliferation, and remodeling, regulated by immune cells, cytokines, growth factor, and extracellular matrix complex. However, this process can be delayed by factors such as microbial infection, prolonged inflammation, oxidative stress, metabolic disorder, and poor vascularization. Chronic wounds represent a major global health burden and are frequently associated with morbidity, reduced quality of life, and increased economic cost to healthcare systems.<sup>[1]</sup>

The inflammation phase plays a major role in wound healing process by initiating immune defense and preparing the wound bed for repair. Yet, the excessive and persistent inflammation disrupts the tissue and damage through over production of inflammatory mediators such as Nitric Oxide (NO), Tumor Necrosis Factor- $\alpha$

(TNF- $\alpha$ ). Recent findings emphasis that dysregulation of inflammatory pathway and oxidative stress and the epithelial barrier impairment contribute to the pathogenesis of several inflammatory conditions. Therefore, controlling inflammation is confirmed a critical therapeutic strategy in enhancing tissue repair and prevent chronic wound progression. Medical plants have used across cultures for the management of wounds and inflammatory disorders due to rich active compounds, including phenols, flavonoids, tannins, saponins, terpenoids and alkaloids. These phytochemicals exhibit antioxidant, antimicrobial, collagen promoting and anti-inflammatory activities, which collectively support wound contraction, reepithelialization, and tissue remodeling.<sup>[2]</sup>

## *Cassia fistula*

The golden Shower Tree or *Cassia fistula* L., is a member of the Fabaceae family.<sup>[3]</sup> It is extensively dispersed in tropical countries, including Nepal, India, Myanmar, Malaysia and portions of China, Brazil, South Africa and West Indies. It is native to the Indian subcontinent and Southeast Asia. It is typically found in Monsoon and deciduous forests in India, where it may grow up to 1,300 meters in the outer Himalayan range.<sup>[4]</sup> It prefers dry conditions, well-drained soils and full sun. Amaltas (Hindi), Konrai (Tamil), Aragvadh (Telugu) are its colloquial names.<sup>[5]</sup> Flavonoids (quercetin, kaempferol), anthraquinones



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(rhein, emodin), phenolic compounds, tannins, saponins, glycosides, alkaloids and terpenoids (lupeol) are among the phytochemical components found in *Cassia fistula*. Different plant parts have different functions. For example, flower and leaves have antioxidant, antimicrobial and anti-inflammatory effects. Pods have antioxidant and laxative properties. Seeds have antidiabetic and antimicrobial qualities. Bark has antimicrobial and anti-inflammatory properties and roots have hepatoprotective and antioxidant properties. Antioxidant, anti-inflammatory, antibacterial, antidiabetic, hepatoprotective, anticancer, neuroprotective, anti-obesity, antiparasitic and immunomodulatory qualities are among the pharmacological characteristics of *Cassia fistula*.<sup>[6]</sup> Free radicals are neutralised, cytokines are controlled and inflammatory enzymes are inhibited by its antioxidant and flavonoid-rich extracts. Significant anti-inflammatory action is confirmed by experimental tests in granuloma and carrageenan-induced models, with results similar to those of diclofenac sodium. Additionally, *Cassia fistula* accelerates contraction, collagen synthesis and epithelial regeneration, all of which aid in wound healing. Through the combined action of flavonoids, anthraquinones and triterpenes, methanolic and aqueous extracts improve tissue healing and histological recovery, underscoring the plant's promise as a natural therapeutic agent for wound and inflammation management.<sup>[7]</sup>

### ***Murraya koenigii***

The curry leaf tree, *Murraya koenigii* (L.) Spreng, is a member of the Rutaceae family and is indigenous to India, Sri Lanka and Other parts of South Asia. It is a fragrant, semi-deciduous shrub or small tree with a short stem, dense, shaded crown and grey bark that can reach a height of 6 meters. The plant produces white, fragrant, funnel-shaped blooms in terminal cymes, and the bipinnate leaves are 15-30 cm long with 11-25 ovate-lanceolate leaflets. When ripe, the ovoid, purplish-black fruits usually have two green seeds. Curry leaves (English), Kariveppilai (Tamil), Karipatta (Hindi), and Karibeve (Kannada) are some of its colloquial names. According to phytochemical analyses, the leaves include proteins, amino acids, sterols, alkaloids, flavonoids, phenolics and saponins. Carbazole alkaloids (koenigine, mahanimbin, girinibin and koenidine), coumarins, triterpenoids and a variety of vitamins and minerals are important components. These substances provide carbs, fibre, vitamin C, carotene and vital minerals and they also contribute to the plant's bitterness, haemolytic activity and nutritional value.<sup>[8]</sup> *M. koenigii* has a wide range of pharmacological properties, including antibacterial, antioxidant, anticancer, anti-inflammatory, anti-fungal, anthelmintic, antihypertensive, antidiabetic, hypolipidemic and neuroprotective actions.<sup>[9]</sup> Its bioactive substances, such as mahanimbin, koenigine and caryophyllene, reduce blood sugar and cholesterol, scavenge free radicals, suppress infections and enhance heart and memory. By promoting fibroblast proliferation, collagen production and epithelialization

while suppressing pro-inflammatory cytokines (IL-1 $\beta$ , IL-6, TNF- $\alpha$ ) the plant notably exhibits strong anti-inflammatory and wound healing qualities. *Murraya koenigii* is a promising natural therapeutic agent for inflammation-associated wound healing and related illnesses because of these activities and its potential as an antioxidant.<sup>[10]</sup>

### ***Musa paradisiaca***

The banana or plantain, *Musa paradisiaca* (family Musaceae),<sup>[11]</sup> is perennial herbaceous plant that resembles a tree and grows to a height of 10 to 40 feet. It is found across tropical and subtropical countries. Originating in India and Burma, it is widely distributed in Indian states including Tamil Nadu, Andhra Pradesh, Bihar, Madhya Pradesh, West Bengal, Maharashtra and Gujarat. It is also grown in regions of Africa, Americas, Australia, and Asia.<sup>[12]</sup> Kela (Hindi, Marathi), Kadali (Tamil), Kalamalu (Telugu) and Vasha (Malayalam) are its colloquial names.<sup>[13]</sup> *M. paradisiaca* contains flavonoids, alkaloids, glycosides, triterpenes, sterols, vitamins, amino acids and polysaccharides according to phytochemical analysis. Leucocyanidin, Quercetin and its Glycosides, sitoindosides 1-4, sitosterol derivatives, triterpenoids ( $\beta$ -amyrin, lanosterol), catecholamines (serotonin, dopamine, norepinephrine) and essential amino acids like arginine and leucine are important components, along with vitamins B and C, pectin, tannins and minerals like potassium and iron. The plant also produces syringin and other glycosides in its blooms.<sup>[14]</sup> Its adaptogenic, anti-inflammatory and antioxidant qualities are influenced by these bio actives. *M. paradisiaca* has a variety of pharmacological properties including as hepatoprotective, antioxidant, antibacterial, antidiabetic, antiulcer, antihypertensive, analgesic and wound-healing actions. Its extracts lower oxidative stress, increase catalase and superoxide dismutase activity and offer antibacterial defence against staphylococcus, *E. coli* and *klebsiella*. While roots and flower extracts reduce blood sugar and HbA1c, the pulp strengthens the stomach mucosa. By raising hydroxyproline, hexosamine and SOD levels and speeding up tissue repair, collagen deposition and epithelialization, methanolic and aqueous extracts aid in the healing of wounds. Through antioxidant, antibacterial and collagen promoting mechanisms, studies on *M. paradisiaca* and *M. sapientum* var. *paradisiaca* verified their wound-healing efficiency comparable to that vitamin E. When used as a whole, *Musa paradisiaca* is a powerful and safe natural remedy for oxidative stress-related illnesses and wound healing.<sup>[15]</sup>

### ***Anemarrhena asphodeloides***

*Anemarrhena asphodeloides* belongs to the family of Asparagaceae. It is mainly distributed in China, Magnolia and other east Asian regions. Yixian Country of Hebei Province is recognized as the authentic ('Dao-di') producing area, where the medical rhizome of this plant is called as xilinzhimu, known for their superior quality.<sup>[16]</sup> The rhizome is traditionally known

as zhimu in China. The rhizome of anemarrhea contains the steroidal saponins. Timosaponin B II is the major constituent (1.5 to 3.2%) and Timosaponin A II is another constituent responsible for its neuroprotective and antitumor activity (0.1 to 0.8%). The other major constituent is xanthenes (0.01 to 0.5%) responsible for antidiabetic, anti-inflammatory, and antioxidant property. It also contains flavonoids mainly Quercetin and Kaempferol which are found in lower concentration and responsible for antioxidant and vascular protective action. It also contains phenylpropanoid derivatives namely Nyasol which are present in lower concentration which plays a role in neural protective and anti-inflammatory activity.<sup>[17]</sup> Some studies have demonstrated that *Anemarrhena asphodeloides* exhibits anti-inflammatory activity. To evaluate this property, the ethanolic extract of *A. asphodeloides* was tested for its ability to modulate inflammatory mediators in LPS stimulated RAW 264.7 macrophages cells. The results revealed that AA-Ex downregulated the expression of key pro-inflammatory cytokine genes, including IL-1 $\beta$ , IL-6, TNF- $\alpha$ , and COX-2, indicating its strong inhibitory effect on inflammatory signalling pathway. The play active constituents such as Timosaponin A II and Timosaponin B II also suppress the LPS-induced overproduction of NO and ROS in RAW 264.7.<sup>[18]</sup>

### **Lawsonia inermis**

*Lawsonia inermis* belongs to lythraceae. It is originated in North Africa and South West Asia and it was presently cultivated across tropical regions as both an ornamental and a natural dye yielding plant. It is much branched, smooth an oppositely arranged, nearly sessile, measuring, a short glabrous petiole and an acute to obtuse apex tapering at the base. It is also known as much branched, smooth shrub or small tree generally reaching 2 to 6 m in height. The leaves are small and oppositely arranged, nearly sessile, measuring 1.5 to 5 cm long and 0.5 to 2 cm width, elliptic to broad lanceolate with entire margins, a short glabrous petiole and an acute to obtuse apex tapering at the base. It is also known as Henna (English), Medhi, Medhika (Sanskrit), Marudhani, Aivani, Alyanam (Tamil), Goranta (Telugu).<sup>[19]</sup> *Lawsonia* contains lawsone as a major dye component along with tannins, resins, flavonoids (esculetin, fraxetin, scopoletin),  $\beta$ -sitosterol and small quantities of essential oil. The flowers contain 0.002% of essential oil, predominantly composed of  $\beta$ -ionone. The bark is rich in isoplumbagin, hennadiol and long chain alcohols. The seeds contain proteins, carbohydrates, fibres and unsaturated fatty acids. The plant has various pharmacological actions such as antidiabetic activity, immunomodulatory activity, hepatoprotective activity, antioxidant activity, antibacterial activity, antimicrobial activity, antifungal activity, analgesic and anti-inflammatory activity and wound healing properties.<sup>[20]</sup>

*Lawsonia inermis* was scientifically evaluated for the wound healing and antimicrobial effects, particularly against diabetic foot ulcer complicated by Multidrug Resistant (MDR) infection. Ethanolic extract of *L. inermis* were analysed using UPLC -MS/

MS and Global Natural Products Social Molecular Networking (GNPS), identifying 93 bioactive compounds, mainly phenolic acids and flavonoids such as quercetin, apigenin and chrysin. *In vivo* experiments on diabetic rats revealed restoring of normal epidermal architecture. Molecular analysis showed downregulation of pro inflammatory genes (TNF- $\alpha$ , CASPASE-3) and upregulation of growth of anti-inflammatory markers (TGF- $\beta$ , IL-10, VEGF-B), indicating simultaneous anti-inflammatory and degenerative effects.<sup>[21]</sup>

### **Vernonia amygdalina**

*Vernonia amygdalina* or bitter leaf belongs to the family of Asteraceae. *Vernonia amygdalina* is the most prominent and most cultivated species of genus *Vernonia*. The plant was majorly found in Africa and Asia. It is a wooded shrub of about 2 to 10 cm height that can be regenerate after planted. It is also known as bitter leaf (English), Malaysia (South Africa), Musikavakadzi (Zimbabwe), Ikaruga (China), Olulusia (Kenya).<sup>[22]</sup> The nutritional constituents present in this plant are proteins, fats, carbohydrates, polyphenols, vitamins C, A, E, B1, B2. The phytochemical constituents present in this plant are sequestrene lactone (vernodalinalol, vernolepin, vernomygdin, hydroxyvernodiline, vernolide and vernodolol) had been reported that inhibit breast cell cancer growth. It also contains flavonoids, tannins, saponins and triterpenoids that are responsible for the antioxidant and anti-inflammatory activity. *Vernonia amygdalina* has various pharmacological activities such as anti-inflammatory, anti-allergic, anticancer, antimicrobial and antileukemia activity.<sup>[23]</sup>

The wound-healing potential of *Vernonia amygdalina* has been investigated by Mumuni *et al.*, who conducted an excision wound study on five groups of Albino rats. Circular wounds were created on the dorsal region, and the groups received topical treatments with 2.5% and 5.0% methanolic extracts of freshly squeezed *V. amygdalina* leaves, as well as neomycin powder, applied every three days for 24 days. A control group received no treatment. After 24 days, all treated groups achieved complete (100%) wound closure, while the untreated control group showed only 88% closure, with a residual wound area of 0.23 $\pm$ 0.08 cm, reflecting the slower natural healing process.<sup>[24]</sup>

### **Curcuma longa**

*Curcuma longa* [Haldi] belongs to the family of Zingiberaceae. It is a perennial herb that grows up to one meter tall, characterized by a short stem and oblong, ovate, yellow-colored rhizomes that are aromatic and often branched. Rhizome is extensively used as a culinary spice as well as in traditional medicine. Turmeric has been employed to manage digestive ailments, wounds, rheumatism, sinusitis and liver disorder due to its therapeutic properties<sup>[25]</sup> and it is globally distributed in India, China, Thailand, Indonesia, Singapore, Philippines, Malaysia, Australia as a primary location for turmeric cultivation. India alone accounts for nearly 80% of the world's turmeric production, followed by China [8%],

Myanmar [4%] and Bangladesh and Nigeria [3%]. The Chinese provinces such as Sichuan, Yunnan, Fujian, Guangdong, Taiwan are recognized as important producers of turmeric.<sup>[26]</sup> It is widely recognized by various vernacular names across India like Haldi in Hindi, Bengali, Marathi, Gujarati, and Arisina in Kannada, Manjal in Tamil, Pasupu in Telugu, and Haridra in Sanskrit.<sup>[27]</sup> The constituents of turmeric are Curcumin, Desmethoxycurcumin, Methyl curcumin, Sodium curcumin. The pharmacological activity of the curcuma includes Antioxidant, Anti-inflammatory, Antidiabetic, Antitumor and hepatoprotective. By encouraging collagen synthesis, fibroblast proliferation, epithelialization angiogenesis, cytokine secretion and quicker wound closure, curcumin improves wound healing.<sup>[28]</sup>

### ***Moringa olifera***

*Moringa oleifera* belongs to the Moringaceae family and is sometimes referred to as the drumstick tree or horse radish tree. It originated in India and is currently grown extensively in tropical and subtropical regions of the world. Along with minerals like iron, calcium, potassium and bioactive substances like flavonoids, phenolic acids, tannins, and alkaloids, its leaves are a rich source of vitamins A, C, E, and B-complex. These components provide the plant with strong antibacterial, anti-inflammatory, and antioxidant qualities that promote wound healing. *Moringa* leaves are prized for their nutritional and medicinal qualities and have historically been used to treat wounds, inflammation, and skin conditions.<sup>[29]</sup> Originating in the sub-Himalayan regions of northern India and Pakistan, *Moringa oleifera* is now widely produced in tropical and subtropical regions of Africa, Asia, and the America including Ethiopia, Florida, Sudan, the Caribbean and the Philippines.<sup>[30]</sup> *Moringa* also identified as Sajina (Bengali), Murungai [Tamil], Mulaga, Munaga, and Tellamunga [Telugu]. The phytochemical constituents of *Moringa* are Niazimicin, Niaziminin A & B, 4-( $\alpha$ -rhamnopyranosyloxy) benzyl glucosinolate (RPBG), Quercetin, Isoquercitrin, Rhamnetin, 4-Hydroxymellein, Benzylamine (3). *Moringa oleifera* helps wounds heal in several ways: it lowers inflammation by reducing TNF- $\alpha$ , IL-1 $\beta$ , and IL-6 levels; increases antioxidant enzymes (SOD, catalase, and glutathione peroxidase) to fight oxidative stress; Additionally, the extract boosts fibroblast proliferation, promotes angiogenesis, and exhibits antibacterial action against *Staphylococcus aureus*, all of which speed up wound healing and regeneration.<sup>[31]</sup>

### ***Tinospora cordifolia***

The climbing shrub *Tinospora cordifolia*, also known as Giloe, Gurcha, Gulvel, and Gilo, has succulent stems with fleshy aerial roots. The leaves have long petioles and are heart-shaped, simple, and alternating. In summer, it bears yellowish-green unisexual flowers on leafless stalks; in winter, it produces crimson to

orange-red drupes. The bark has pronounced lenticels and is warty, spirally grooved, and grey, brown in color.<sup>[32]</sup> It is widely distributed in India, China, some parts of Australia, Srilanka, Myanmar, Pakistan. It is also known as *Tinospora* in English; Gilo in Punjabi; Guluch in Oriya; Gulvel in Marathi; Chittamrutu in Malayalam; Amrita in Kashmiri. Tinosporide, furanlactone, diterpene, and furanoid are among the terpenoids found. Notable components of the alkaloids are tinosporine, magnoflorine, berberine, and choline. Tinosporocolumbin and clerodane derivatives are two of the diterpenoid lactones found. Furthermore, the plant includes glycosides such as furanoid diterpene glycosides and tinocordifoliside (3). The various pharmacological activities are Antioxidant, Antidiabetic, Hepatoprotective, Anticancer.<sup>[33]</sup> The *Tinospora cordifolia* extract contains several bioactive compounds that contribute to its anti-inflammatory effect. N-Hexadecenoic acid (22.37%) exhibits strong anti-inflammatory potential by blocking pro-inflammatory mediators, as supported by structural and kinetic studies. 9-Octadecenoic acid (1.98%) reduces excessive inflammatory signaling by limiting Nitric Oxide (NO) production in LPS-stimulated macrophages. Additionally, Cholesta-4,6-dien-3 $\beta$ -ol, Stigmasterol,  $\beta$ -sitosterol stearate, and Cholest-4-en-3-one which are plant sterols and terpenoids-help regulate immune responses by suppressing inflammatory cytokines. Together, these phytoconstituents inhibit the release of TNF- $\alpha$ , IL-6, and NO, while downregulating the expression of COX-2 and iNOS, two major enzymes associated with inflammation.<sup>[34]</sup>

### ***Coccinia grandis***

The scientific name of this plant is *Coccinia grandis*, which belongs to the family of Cucurbitaceae. The geographical origins of the plant are India, Bangladesh, China, Malaysia, Pakistan, Kenya, and Thailand.<sup>[35]</sup> The vernacular names for this plant are Dhonda (Telugu), Tondekai (Kannada), Kova (Malayalam), Kandoori (Hindi), and Kovakkodi (Tamil).<sup>[3]</sup> This plant has constituents like nutrients such as iron, calcium, and phosphorus; antioxidants; bioactive compounds like flavonoids, ascorbic acid, and beta carotene; and biologically active compounds like alkaloids, saponins, cucurbitacin, glucosides, etc.<sup>[36]</sup> The *Coccinia grandis* has pharmacological activities such as antioxidant, antidiabetic, anticancer, antiviral, antidyslipidemic, immunomodulatory, and spasmolytic.<sup>[35,37]</sup> This plant also has anti-inflammatory properties, in which a recent study (Rahman *et al.*, 2023) indicates that the methanolic leaf extract of *C. grandis* contains bioactive compounds such as alkaloids, phenols, terpenoids, quinines, glycosides, steroids, tannins, phlobatannins, and proteins, demonstrating significant anti-inflammatory action (IC<sub>50</sub>=51.87  $\mu$ g/mL). The extract exhibits effective membrane stabilizing activity at 10 mg/mL (90.14% $\pm$ 0.942%) compared to standard indomethacin (93.63% $\pm$ 0.910%) in hypotonicity-induced lysis of erythrocyte membrane.<sup>[35]</sup>

### **Carica papaya**

The scientific name of the plant is *Carica papaya*, which belongs to the family of Caricaceae. The geographical origins of this plant are the United States of America, Colombia, India, Indonesia, Brazil, New Zealand, Sri Lanka, and Thailand.<sup>[38]</sup> *Carica papaya* has various vernacular names like papeeta (Hindi), pappali (Tamil), pappayam (Malayalam), and boppayi (Telugu).<sup>[27]</sup> The fruit of this plant contains constituents like linalool, caffeic acid, and lycopene. The leaves' part contains quercetin and 5,7-dimethoxycoumarin. The shoot contains calcium, iron, and magnesium. The other constituents, like papain, chymopapain, caricain, chitinase, etc.<sup>[38]</sup> *Carica papaya* has various pharmacological activities like antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, anticancer, and antidiarrheal.<sup>[39]</sup> The *Carica papaya* has a wound-healing property in which the vitamin K promotes blood-clotting elements that aid in the regeneration of the dermis, which is a necessary step in wound healing. Extracts from papaya epicarp have been demonstrated to be useful in the treatment of wounds. In order to avoid infection and produce a granulating wound, papain and chymopapain can be applied topically to pediatric infected burns (Leitaoet *al.*, 2022).<sup>[40]</sup>

### **Aegle marmelos**

The scientific name of this plant is *Aegle marmelos*, which belongs to the family of Rutaceae. The geographical origins of this plant are India, Thailand, Bangladesh, Pakistan, Sri Lanka, Nepal, and Myanmar.<sup>[41]</sup> The plant has other names like vilvam (Tamil), Maredu (Telugu), vilvam (Malayalam), and Bael tree (English).<sup>[27]</sup> The *Aegle marmelos* has various constituents like alkaloids, coumarins, terpenoids, phenolic acid, flavonoids, tannins, amino acids, organic acids, and fatty acids. It has various pharmacological activities like anti-inflammatory, anti-diarrheal, hepatoprotective, anti-cancer, cardioprotective, anti-hyperlipidemic, anti-ulcer, and anti-diabetic.<sup>[42]</sup> AMF (1%, 2%, and 3%) stimulates the healing of wounds. In rats, topical treatment accelerated re-epithelialization and reduced the extent of wounds. With AME, hematoxylin and eosin staining revealed normal tissue structure. Targeting inflammation, cell proliferation, and tissue remodeling phases, it promotes collagen synthesis, ECM remodeling, and keratinocyte proliferation, aiding in tissue healing and re-epithelialization.<sup>[43]</sup>

### **Centella asiatica**

*Centella asiatica* or Indian pennywort (Apiaceae)<sup>[44]</sup> which is also called as Braham Manduki in hindi, Ondelaga, Brahmi soppu in kannada, vallarai in Tamil, kodangal in Malayalam, Khodabrahmi in Gujrati.<sup>[45]</sup> *Centella asiatica* thrives in moist sandy or clay soils rich in organic matter, up to 600-700 m altitude. It commonly grows in tropical and subtropical swampy areas of India, Southeast Asia, Sri Lanka, China, and South Africa.<sup>[44]</sup> They have various phytochemical constitution phenolic compound like Irbic acid, Iso - chologenic acid (A, B and C) and Flavonoids like Quercetin,

kaempferol, catechin and triterpenoids and saponins like Asiaticoside, Brahmoside, centelloside and minor constitution like fatty acids, volatile components, amino acid etc.<sup>[46]</sup> The plants having various pharmacological properties like anti-oxidant, anti-inflammatory, anti-ulcer, neuroprotective, nootropic, wound healing, anti-cancer properties.<sup>[44]</sup> The study was explained *Centella asiatica* contains triterpenoid saponins such as asiaticoside, asiatic acid, and madecassic acid, which show strong anti-inflammatory and antioxidant activities. They inhibit COX and LOX pathways, reducing PGE<sub>2</sub> and inflammatory cytokines. The extracts enhance antioxidant enzymes like catalase and SOD, helping to reduce swelling similar to ibuprofen. Overall, these compounds protect against oxidative stress, improve skin barrier function, and promote faster healing of damaged or inflamed skin. Asiaticoside, the main compound in *Centella asiatica*, promotes wound healing by enhancing collagen synthesis, fibroblast growth, and angiogenesis. It regulates TNF- $\alpha$ , IL-6, and growth factors, reducing inflammation and strengthening skin. Studies confirm its role in improving collagen formation, tissue repair, and wound contraction for effective skin regeneration.<sup>[46]</sup>

### **Mangifera indica**

*Mangifera indica* belongs to the family of Anacardiaceae.<sup>[47]</sup> The mango was first origin in Indo-Burma region and later they have cultivated in India for over 4000 or even 6000 years, commercial fruit in many nations like the regions of southeast Asia, the Philippines, Indonesia, Java, Thailand, Burma, Malaya, and Ceylon.<sup>[48]</sup> Mangoes can be produced in both tropical and subtropical climates in areas with dry summers and plenty of water. The other common name is Aam in Hindi, mambalam in Tamil, Choothaphalam in Malayalam, Amb in Punjab. The phytochemical constituents Mangiferin are present all part of the plants expect the Root other like polyphenols such as quercetin, gallic acid, kaempferol, ellagic acid, catechins, and anthocyanins and Carotenoids like  $\beta$ -carotene, luteoxanthin, and zeaxanthin Terpenoids (myrcene, limonene, terpinolene), while triterpenoids (lupeol, lupeollinoleate), tannins, tocopherols, and resorcinolic lipids. They have various pharmacological activities like antioxidant, antidiabetic, anti-inflammatory, anticancer, Hepatoprotective activities etc.<sup>[47]</sup> Methanolic leaf extract of *Mangifera indica* (MEMI) exhibited significant, dose-dependent anti-inflammatory effects in carrageenan-induced rat paw edema, showing 43.8% and 53.7% inhibition at 200 and 500 mg/kg, respectively, compared to 57.3% with indomethacin (10 mg/kg). The higher MEMI dose showed activity nearly equivalent to the standard drug. Mangiferin, the key bioactive compound in mango leaves, exerts anti-inflammatory effects by inhibiting COX-2 and modulating histamine, serotonin, prostaglandins, and leukotrienes. Toxicity studies show safety up to 5 g/kg, highlighting its potential as a safe, natural, and cost-effective anti-inflammatory agent.<sup>[49]</sup>

## Boswellia serrata

*Boswellia serrata* belonged to the family of Burseraceae. Its other name is Indian frankincense tree in English, Parang in Telugu, kundru in Hindi, chilakdhupa, tallaki in Kannada.<sup>[50]</sup> They are distributed in tropical Asia and Africa are home to a *Boswellia* genus. India is having two species, Indian olibanum tree, *B. serrata*. The tree is widespread in Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Bihar etc. It generally thrives in tropical regions; they are seasonally dry. Flowering in the season of Jan-May, sept-dec and fruit in the season April-Aug, Nov-march.<sup>[51]</sup> It contains oleo gum resin contains oil, terpenoids, and other bioactive compounds. It comprises water-soluble polysaccharides (65%), resins (30-60%), and essential oil (5-10%). The essential oil mainly consists of monoterpenoids such as  $\alpha$ -pinene (73.3%), along with cis-verbenol, borneol, myrcene, and limonene.<sup>[50]</sup> The resin contains monoterpenes, diterpenes, triterpenes, and tetracyclic triterpenic acids. Four key pentacyclic triterpenic acids- $\beta$ -boswellic acid, acetyl- $\beta$ -boswellic acid, 11-keto- $\beta$ -boswellic acid, and Acetyl-11-Keto- $\beta$ -Boswellic Acid (AKBA)-are the main bioactive compounds responsible for anti-inflammatory effects.<sup>[52]</sup> It contains various pharmacological activities analgesic, anti-arthritis, immunomodulatory, respiratory problem, antioxidant anti -cancer activity.<sup>[50]</sup> Boswellic acids inhibit 5-Lipoxygenase (5-LO), reducing leukotriene-mediated inflammation without affecting glycosaminoglycan synthesis. They also block NF- $\kappa$ B and HLE, decreasing edema and arthritis symptoms. AKBA shows the strongest 5-LO inhibition and suppresses VEGFR2-mediated angiogenesis, offering anti-cancer benefits. Clinical studies show improvement in rheumatoid and osteoarthritis with minimal side effects.<sup>[53]</sup>

## CONCLUSION

Tissue repair and regeneration depend on the interconnected physiological processes of wound healing and anti-inflammatory actions. By eliminating pathogens and injured cells, inflammation starts the healing process. Tissue remodelling and proliferation come next. Through antioxidant action, collagen synthesis promotion, and inflammatory mediator modulation, natural products-particularly those high in flavonoids, terpenoids and phenolic compounds-show notable wound healing and anti-inflammatory properties. These bioactive substances promote angiogenesis, fibroblast proliferation and epithelialization, which accelerates wound healing. Therefore, investigating natural therapeutic agents offers a viable and secure substitute for synthetic medications for efficient wound care and inflammation control.

## ABBREVIATIONS

**TNF- $\alpha$** : Tumor Necrosis Factor Alpha; **NO**: Nitric Oxide; **IL**: Interleukin; **SOD**: Superoxide Dismutase; **VEGF**: Vascular Endothelial Growth Factor; **ECM**: Extracellular Matrix; **LPS**:

Lipopolysaccharides; **COX**: Cyclooxygenase; **MDR**: Multidrug Resistant; **AMF**: Aegle Marmelos Fraction; **HbA1c**: Glycated Hemoglobin; **AKBA**: Acetyl-11-keto- $\beta$ -boswellic acid.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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