



WOUND HEALING POTENTIAL OF SOME MEDICINAL PLANTS

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ABSTRACT

Wounds are inescapable events in life. Wounds may arise due to physical, chemical or microbial agents. Healing is survival mechanism and represents an attempt to maintain normal anatomical structure and function. Wound healing is a process by which tissue regeneration occurs. Plants and their extracts have immense potential for the management and treatment of wounds. The phyto-medicines for wound healing are not only cheap and affordable but are also purportedly safe as hyper sensitive reactions are rarely encountered with the use of these agents. These natural agents induce healing and regeneration of the lost tissue by multiple mechanisms. In this review we have made an attempt to give an insight into the different plants having potential wound healing properties which could be beneficial in therapeutic practice.

Keywords: Wounds, Wound healing, Herbs, Phyto-medicines.

INTRODUCTION

India has a rich flora that is widely distributed throughout the country. Herbal medicines have been the basis of treatment and cure for various diseases and physiological conditions in traditional methods practiced such as Ayurveda, Unani and Siddha. Medicinal components from plants play an important role in conventional as well as western medicine. Plant derived drugs have been a part of the evolution of human, healthcare for thousands of years. Plant based drugs were commonly used in India and China. Today a substantial number of drugs are developed from plants which are active against a number of diseases. The majority of these involve the isolation of the active ingredient (chemical compound) found in a particular medicinal plant and its subsequent modification. One of the survey conducted by the WHO reports that more than 80% of the world's population still depends upon the traditional medicines for various diseases. In the developed countries 25 percent of the medical drugs are based on plants and their derivatives and the use of medicinal plants is well known among the indigenous people in rural areas of many developing countries¹⁻⁵.

A wound may be defined as a break in the epithelial integrity of the skin or may also be defined as a loss or breaking of cellular and anatomic or functional continuity of living tissue. According to the Wound Healing Society, wounds are physical injuries that result in an opening or break of the skin that cause disturbance in the normal skin anatomy and function. They result in the loss of continuity of epithelium with or without the loss of underlying connective tissue^{6,7}.

Current estimates indicate the worldwide nearly 6 million people suffer from chronic wounds. Unhealed wounds constantly produce inflammatory mediators that produce pain and swelling at the wound site. Wounds are a substrate for infection and prolong the recovery of

injured patients. Chronic wounds may even lead to multiple organ failure or death of the patients. Wounds are the physical injuries that result in an opening or breaking of the skin and appropriate method for healing of wounds is essential for the restoration of disrupted anatomical continuity and disturbed functional status of the skin⁸⁻¹⁰.

CLASSIFICATION OF WOUNDS

Wounds are classified as open and closed wound on the underlying cause of wound creation and acute and chronic wounds on the basis of physiology of wound healing.

Open wounds

In this case blood escapes the body and bleeding is clearly visible. It is further classified as: Incised wound, Laceration or tear wound, Abrasions or superficial wounds, Puncture wounds, Penetration wounds and gunshot wounds¹¹.

Closed wounds

In closed wounds blood escapes the circulatory system but remains in the body. It includes Contusion or bruises, hematomas or blood tumor, Crush injury etc.

Acute wounds

Acute wound is a tissue injury that normally precedes through an orderly and timely reparative process that result in sustained restoration of anatomic and functional integrity. Acute wounds are usually caused by cuts or surgical incisions and complete the wound healing process within the expected time frame¹².

Chronic wounds

Chronic wounds are wounds that have failed to progress through the normal stages of healing and therefore enter a state of pathologic inflammation chronic wounds either



require a prolonged time to heal or recur frequently. Local infection, hypoxia, trauma, foreign bodies and systemic problems such as diabetes mellitus, malnutrition, immunodeficiency or medications are the most frequent causes of chronic wounds^{13,14}.

MECHANISM OF WOUND HEALING

The response to injury, either surgically or traumatically induced, is immediate and the damaged tissue or wound then passes through three phases in order to affect a final repair:

- The inflammatory phase
- The fibroplastic phase
- The remodelling phase

The inflammatory phase prepares the area for healing and immobilizes the wound by causing it to swell and become painful, so that movement becomes restricted. The fibroplastic phase rebuilds the structure, and then the remodelling phase provides the final form

The Inflammatory phase

The inflammatory phase starts immediately after the injury that usually last between 24 and 48 hrs and may persist for up to 2 weeks in some cases The inflammatory phase launches the haemostatic mechanisms to immediately stop blood loss from the wound site. Clinically recognizable cardinal sign of inflammation, rubor, calor, tumor, dolor and function-laesa appear as the consequence. This phase is characterized by vasoconstriction and platelet aggregation to induce blood clotting and subsequently vasodilatation and phagocytosis to produce inflammation at the wound site¹⁵.

The fibroplastic phase

The second phase of wound healing is the fibroplastic phase that lasts upto 2 days to 3 weeks after the inflammatory phase. This phase comprises of three steps viz., granulation, contraction and epithelialisation. In the granulation step fibroblasts form a bed of collagen and new capillaries are produced. Fibroblast produces a variety of substances essential for wound repair including glycosaminoglycans and collagen. Under the step of contraction wound edges pull together to reduces the defects in the third step epithelial tissues are formed over the wound site¹⁶.

The Remodeling phase

This phase last for 3 weeks to 2 years. New collagen is formed in this phase. Tissue tensile strength is increased due to intermolecular cross-linking of collagen via vitamin-C dependent hydroxylation. The scar flattens and scar tissues become 80% as strong as the original^{17,18}.

The wound healing activities of plants have since been explored in folklore. Many Ayurvedic herbal plants have a very important role in the process of wound healing. Plants are more potent healers because they promote the

repair mechanisms in the natural way. Extensive research has been carried out in the area of wound healing management through medicinal plants. Herbal medicines in wound management involve disinfection, debridement and providing a moist environment to encourage the establishment of the suitable environment for natural healing process¹⁹.

MEDICINAL PLANTS WITH SIGNIFICANT WOUND HEALING ACTIVITY

Recent studies with significant findings for wound healing characteristic of some medicinal plants are emphasized here.

Rubia cordifolia Linn.

Rubia cordifolia Linn. (Rubiaceae) also known as, Manjistha, Indian madder, distributed throughout India. The roots of this plant are of high medicinal value and are recognized as official. *Rubia cordifolia* has a variety of uses such as blood purifier, immunomodulator, anti-inflammatory and antioxidant. It is helpful in treating skin diseases, in blood purification, increasing appetite and in stimulation and contraction of uterus. Ethanol extract showed the presence of anthraquinone glycosides, saponins, tannins and phytosterols. Tannins and anthraquinones are the major phyto-constituent present in this plant which may be responsible for wound healing action^{20,21}.

Ocimum kilimandscharicum

Ocimum kilimandscharicum, belonging to family Lamiaceae. It is an aromatic undershrub with pubescent quadrangular branchlets. It is an indigenous medicine for a variety of ailments like cough, bronchitis, viral infections, anorexia, and also wounds. It contains tannins, flavonoids, proteins and other important constituents. Flavonoids possess antioxidant and free radical scavenging effect, wound healing, antibacterial property²².

Tephrosia purpurea Linn.

Tephrosia purpurea Linn. belonging to family Leguminosae. It also called as "Sarwa Wranvishapaka". It contains glycosides, rotenoids, isoflavones, flavonones, chalcones, flavonoids and sterols. According to Ayurvedic system of medicine various parts of this plant are used as remedy for impotency, asthma, diarrhoea, gonorrhoea, rheumatism, ulcer and urinary disorders. An also it cures diseases of kidney, liver, spleen, heart and blood. The dried herb is tonic, laxative, diuretic and also used in the treatment of bronchitis, boils, bleeding piles, pimples, roots and seeds are used as insecticidal, vermifuge, leprosy wound. And the juice is used for the eruption on skin. Decoction is used in vomiting. An extract of pods is effective for pain, inflammation²³.

Aloe vera Linn.

Aloe vera Linn. (Liliaceae) is one of the oldest healing plants known to mankind. It is used topically for cuts,



burns, insects stings, bruises, acne and blemishes, poisoning, welts, skin lesions, eczema, sunburns. A 62.5% reduction in wound diameter was noted in mice receiving 100 mg/kg/day oral Aloe vera and a 50.80% reduction was recorded in animals receiving topical 25% Aloe vera. These data suggest that Aloe vera is effective in wound healing. Aloe vera leaf contains Vitamin C, Vitamin E and amino acids which are essential for wound healing²⁴.

Kigelia pinnata Sausage

Kigelia pinnata Sausage belonging to Bignoniaceae is a small tree found in south, central and west Africa and also in India. The main constituents found in the bark of *Kigelia pinnata* are naphthoquinones lapachol, phenyl propanoid, stigmasterol, β -sitosterol and small amounts of free ferlic acid, p-coumeric acid and 6-methoxymelenin. The bark have also been pharmacologically documented to possess antiamebic, antifungal, antiulcer, antibacterial, antioxidant activities and also shows significant wound healing activity²⁵.

Musa sapientum var. paradisiacal

Musa sapientum var. *paradisiacal* belonging to family Musaceae. It contains flavonoids (leucocyanidin) sterylacyl glycosides and sitoindosides I-IV. Sitoindoside IV was reported to mobilize and activate peritoneal macrophages with increase in DNA and [3H] thymidine uptake. Flavonoids are known to reduce lipid peroxidation flavonoids are also known to promote the wound healing process mainly due to their astringent and antimicrobial property, which results to be responsible for wound contraction and increased rate of epithelialisation. Extensive investigations regarding anti-ulcerogenic and ulcer healing activities of plantain banana have been carried out for the past 30 years. Both methanolic and aqueous extracts (100 mg/kg) when studied for incision and dead space wounds parameters, increased wound breaking strength and levels of hydroxyproline, hexuronic acid, hexosamine, superoxide dismutase, reduced glutathione in the granulation tissue and decreased percentage of wound area, scar area and lipid peroxidation when compared with the control group^{26,27}.

Sphaeranthus indicus Linn.

Sphaeranthus indicus Linn. belongs to family Asteraceae. The plant is mainly used for the epileptic conditions (Convulsions), mental illness and hermicranias. The external application of this paste is used for the treatment of pruritus and edema, arthritis, filariasis, gout and cervical adenopathy. It mainly contains essential oil, ocimene, α -tempinene, methyl-chavical, α -citrol, α -ionon, β -ionone, d-cadinene, p-methoxycyn, unamaldehyde and alkaloid Sphaeranthine^{28,29}.

Ageratum conyzoides Linn.

Ageratum conyzoides Linn. belonging to Asteraceae is a common weed found everywhere in India and commonly known as goat weed, white weed, in various parts of

India. The leaves are applied to the wounds act as septic and healed quickly³⁰.

Hyptis suaveolens Linn.

The plant, *Hyptis suaveolens* Linn. belongs to family Lamiaceae. The extract of *Hyptis suaveolens* contains steroids, alkaloids, carbohydrates, proteins, flavonoids, tannins, glycosides, leaves of this plant used as stimulant, carminative, sudorific, galactagogue, parasitic cutaneous disease, leaf extracts used as a relief to colic and stomachaches leaves and twigs are acts as anti-rheumatic and anti-suporific bats, anti-inflammatory anti-fertility. The plant continues to use in the treatment of wound³¹.

Tectona grandis Linn.

Tectona grandis Linn. is commonly known as Indian teak, and belongs to family Verbinaceae. It contains mainly carbohydrates, tannins and anthraquinone glycosides. *Tectona grandis* is used as anti-inflammatory agents and also used topically for the treatment of burns. It is mainly used for the injuries like burn, inflicted wound and skin ulcers. The extract applied topically or given orally promoted the breaking strength, wound contraction and collagenation³².

Tephrosia purpurea Linn.

Tephrosia purpurea Linn. belongs to family Leguminosae. It also called as "Sarwa Wranvishapaka". It contains glycosides, rotenoids, isoflavones, flavnones, chalcones, flavonoids and sterols. According to Ayurvedic system of medicine various parts of this plant are used as remedy for impotency, asthma, diarrhoea, gonorrhoea, rheumatism, ulcer and urinary disorders. It is also used in the treatment of bronchitis, boils, bleeding piles, pimples, roots and seeds are used as insecticidal, vermifuge, leprous wound and the juice is used for the eruption on skin³³.

Carica papaya Linn.

Carica papaya Linn. belongs to family Caricaceae. Papaya fruits contains a mixture of cysteine endopeptidases such as papain. Chymopapain A and B, papaya endopeptidase II, papaya endopeptidase IV, omega endopeptidase, chinitase, protease-inhibitors, and proteins. Papaya fruits posses wound healing properties, papaya latex was applied to the burn wound using hydrogel as a vehicle system³⁴.

Allium cepa Linn.

Allium cepa Linn. is a member of the Liliaceae, which consists of over 250 genera and 3700 species. *Allium cepa* Linn. is proved to shown the anti-diabetic, anti-oxidant, anti-hypertensive, anti-thrombotic, hypoglycemic, anti-hyperlipidemic. The bulb of *Allium cepa* contains Kampferol, β -sitosterol, ferulic acid, myritic acid, prostaglandins. Bulb extract shown to have ecobolic effect in rats. Traditionally plant containing these constituents used as abortifaciant, the bulb extract of *Allium cepa* had showed ecobolic effect in mice and rats.



Allium cepa treated group showed extensive growth of granulation started along its surface. The treated group of wound showed complete healing of wounds with almost normal architecture of the collagen and reticulin. Increase in tensile strength of treated group wound may be due to increase in collagen concentration, alcoholic extract of *Allium cepa* increase the collagen synthesis³⁵.

Tribulus terrestris Linn.

Tribulus terrestris Linn. is a flowering plant in the family Zygophyllaceae, native to warm temperate and tropical regions of the southern Asia, through out Africa. *Tribulus terrestris* has long been a constituent in tonics in Indian ayurveda practice. Animals studies in rats, rabbits and primates have demonstrated that administration of *Tribulus terrestris* extract produce aphrodisiac activity by increasing the levels of testosterone. The active chemical in *Tribulus terrestris* is likely to be protodioscin. Apart from these it has diuretic, anthelmintic, cytotoxic, Anti-microbial and Anti-fungal activity. Decoction of entire plant is efficacious for anuria, burning micturation, UTI, Obstruction due to growth. The gel containing crude extracts of leaves of *Tribulus terrestris* promoted the breaking strength, wound contraction and period of period of epithelialization. The wound healing activity of *Tribulus terrestris* aqueous leaves extract may at least be in part due to its potent antioxidant activity³⁶.

Gymnema sylvestre R.Br.

Gymnema sylvestre R. Br. is a member of Asclepiadaceae. The leaf has been widely used in Ayurvedic traditional medicine leaves of the plant as anti-diabetes, astringent, bitter, acrid, thermogenic, anti-inflammatory, anodyne, digestive and liver tonic. Tannins and saponin are the chief chemical constituents present in *Gymnema sylvestre* and are known to possess wound healing property. In excision wound models, the percentage of wound area was found to be significantly increased in the animal grouped treated with the extract (16.73%)³⁷.

Morinda citrifolia Linn.

Morinda citrifolia Linn. (Rubiaceae), also known as noni or Indian mulberry, is a small evergreen tree. *Morinda citrifolia* has been heavily promoted for a wide range of uses; including arthritis, atherosclerosis, bladder infections, boils, burns, cancer, chronic fatigue syndrome, circulatory weakness, colds, cold sores, congestion, constipation, diabetes, drug addiction, eye inflammations, fever, fractures, gastric ulcers, gingivitis, headaches, heart disease, hypertension, immune weakness, indigestion, intestinal parasites, kidney disease, malaria, menstrual cramps and irregularities, mouth sores, respiratory disorders, ringworm, sinusitis, sprains, stroke, skin inflammation and wounds. A significant increase in the wound-healing activity was observed in the animals treated with the *Morinda citrifolia* extract compared with those who received the placebo control treatments. The extract treated animals showed a more rapid decrease in wound size and a decreased time to epithelialisation

compared with the control rats which received plain water³⁸.

Anthocephalus cadamba Roxb.

Anthocephalus cadamba Roxb. (Rubiaceae) is widely distributed throughout the greater part of India and is used as a folk medicine in the treatment of fever, anaemia, uterine complaints, blood diseases, skin diseases, leprosy, dysentery, and for improvement of semen quality. The leaves are recommended as a gargle in cases of stomatitis. The major constituents of bark are triterpenes, saponins, indole alkaloids cadambine, 3a-dihydrocadambine, cadamine, isocadamine and isodihydrocadambine. The wound healing activity results showed that upon application of hydro-alcoholic ointment there was a decrease in the epithelization period, along with a visibly decreased scar area. There was also a significant increase in the tensile strength and hydroxyproline content. The crude hydro-alcoholic extract showed significantly stimulated wound contraction. Thus, the plant extract might be useful as a wound healing agent³⁹.

Arnebia densiflora Ledeb.

The genus *Arnebia* are represented by 4 species in the flora of Turkey, one of which, *Arnebia densiflora* Ledeb. belongs to family Boraginaceae, is widespread in Sivas district and known as egnik by local people and used as red colouring for dyeing the carpets and the rugs. *Arnebia densiflora* roots soaked in butter are used in local wound healing care. The roots of this plant have been reported to contain alkannin derivatives, namely β,β dimethylacrylalkannin, teracrylalkannin, isovalerylalkannin, α -methyl-n-butylalkannin. Rats treated with *Arnebia densiflora* showed rapid healing than the control group. Wound closure and collagen production were faster and healing occurred on the 14th day after wounding⁴⁰.

Trigonella foenum-graceum Linn.

Trigonella foenum-graceum Linn. is a member of the Liliaceae. The medicinal attributes of *Trigonella foenum-graceum*, commonly referred to as fenugreek, have been known for a long time. The seed is astringent and is useful for treatment of dysentery and diarrhea. It is a purgative tonic and carminative, and enriches the blood. Furthermore, it is effective in the treatment for ophthalmia, spleen disease, piles, and paralysis. The seeds of the plant are also used as an emollient and anti-diabetic. It is reported to promote milk secretion in nursing mothers, probably through increased prolactin secretion. The seeds also contain a large quantity of folic acid, and they are used as wound healing agent in households. The seed suspension of *Trigonella foenum-graceum* promoted epithelization and an early decrease in the wound surface area. The kinetics of wound contraction and epithelization were improved to a significant level upon oral as well as topical administration of the seed suspension⁴¹.



Napoleona imperialis

Napoleona imperialis is of the family of plants called Lecythidaceae. It is a woody plant, several meters high, found mainly in tropical rain forest. The leaf is used locally as analgesic, tonic, anti-tussive, anti-asthmatic, and wound dressing. The various ointments prepared with *Napoleona imperialis* exhibited a good wound healing effect, a standard antibiotic used in wound healing⁴².

Adhatoda vasica Linn.

Adhatoda vasica Linn. (Acanthaceae) known as chue Mue, grows as weed in almost all parts of the India. Leaves and stems of the plant have been reported to contain an alkaloid mimosine, leaves also contain mucilage and root contains tannins. *Adhatoda vasica* is used for its anti-hyperglycemic, anti-diarrhoeal, anti-convulsant and cytotoxic properties. The plant also contains turgorins, leaves and roots are used in treatment of piles and fistula. Paste of leaves is applied to hydrocele. The methanolic, chloroform and Diethyl ether extract ointment (10%w/w) of *Adhatoda vasica* has significant wound healing activity. In both extract ointment, the methanolic extract ointment (10%w/w) showed significant effect when compare to standard drug and other two extract in excision wound model⁴³.

Catharanthus roseus Linn.

Catharanthus roseus Linn is a member of the Apocyanaceae also known as Vinca Rosea, is native to the Caribbean Basin and has historically been used to treat a wide assortment of diseases. *Catharanthus roseus* has more than 400 known alkaloids, some of which are approved as anti-neoplastic agents to treat leukemia, Hodgkin's disease, malignant lymphomas, neuroblastoma, rhabdomyosarcoma, Wilms' tumor, and other cancers. Its vasodilating and memory-enhancing properties have been shown to alleviate vascular dementia and Alzheimer's disease. Extracts from the dried or wet flowers and leaves of plants are applied as a paste on wounds in some rural communities. An ethanol extract of *Catharanthus roseus* flower has properties that render it capable of promoting accelerated wound healing activity compared with placebo controls⁴⁴.

Carica papaya Linn.

Carica papaya Linn. belonging to the family Caricaceae. The use of *Carica papaya* Linn. in traditional medicine relies on papain, the active principle which exerts an ulcer protective effect. The *Carica papaya* possesses antimicrobial, antioxidant and anti-inflammatory activities. It is reported to heal chronic ulcers as well. The aqueous extract of *Carica papaya* fruit was evaluated for its wound healing activity in streptozotocin-induced diabetic rats using excision and dead space wound models. Extract-treated animals exhibited 77% reduction in the wound area when compared to controls. The extract treated wounds were found to epithelize faster as compared to controls. The wet and dry granulation tissue

weight and hydroxyproline content increased significantly when compared to controls⁴⁵.

Alternanthera brasiliana Kuntz

Alternanthera brasiliana Kuntz belonging to the family Amaranthaceae, is a herbaceous plant commonly known in Brazil as Penicillin or Brazilian Joy Weed, is used against inflammation, cough and diarrhoea in Brazilian popular medicine. The extract of *Alternanthera brasiliana* exhibited anti-nociceptive effect in mice, anti-microbial effect and anti-herpes simplex virus activity. Wound healing activity of methanolic extract of leaves of *Alternanthera brasiliana* Kuntz was studied by excision and incision wound model (*in vivo*) in Sprague Dawley rats. In excision wound model, compared to the control group, per cent contraction of wound was significantly higher in *Alternanthera brasiliana* (5% w/w ointment) treated group. In incision wound model, tensile strength of the healing tissue after treatment with *Alternanthera brasiliana* was found to be significantly higher compared to the control group indicating better wound healing activity of the test plant⁴⁶.

Cordia dichotoma Forst.

Cordia dichotoma Forst. belonging to family Boraginaceae is a medium sized tree with a short, grows in India, Sri Lanka and other warmer countries. The medicinal attributes of *Cordia dichotoma* have been known since long time. Its fruits are used as cooling, astringent, emollient, expectorant, anthelmintic and purgative. Analgesic, anti-inflammatory and hepatoprotective activities have also been reported from the plant. *Cordia dichotoma* treated group showed extensive growth of granulation started along its surface. The treated group of wound showed complete healing of wounds with almost normal architecture of the collagen, reticulin. Increase in tensile strength of treated group wound may be due to increase in collagen concentration, alcoholic extract of *Cordia dichotoma* increase the collagen synthesis⁴⁷.

Lawsonia inermis Linn.

The leaves of *Lawsonia inermis* Linn. (Lythraceae), commonly called as henna are used in the form of a decoction or ointment in the treatment of burns, skin inflammations, wounds and ulcers. The leaves also possess antifungal and antibacterial activities. Henna is reported to contain a naphthaquinone, lawsone, which is a natural dye. It was observed that the oral administration as well as topical application of ethanol extract of henna leaves and lawsone exhibited significant healing response in both the wound models. Further, it was found that the topical application of ethanol extract as well as isolated lawsone was more effective than the same given by the oral route. Thus, topical application of ethanol extract can be successfully formulated for the wound healing activity⁴⁸.



Terminalia bellirica Roxb.

Terminalia bellirica Roxb. belonging to the family Combretaceae, commonly known as belliric myrobalan. Fruit is astringent, antiseptic, rejuvenative, brain tonic, expectorant and laxative. It is used in coughs, sore throat, dysentery, diarrhoea and liver disorders. It is also useful in leprosy, fever and hair care. In folk medicine it has been used for the treatment of skin diseases as antiseptic and on all types of fresh wound. An ethanol extract of *Terminalia bellirica* Fruit has properties that render it capable of promoting accelerated wound healing activity compared with placebo controls⁴⁹.

Vernonia arborea Buch.-Ham.

The plant *Vernonia arborea* Buch.-Ham. is a moderate sized tree belonging to the family Asteraceae. The plant has many medicinal properties, viz. barks juice is used to treat worms, infusion of roots or decoction of bark is given in fever. The healing of the wound was assessed by the rate of wound contraction, period of epithelialisation, skin breaking strength, granulation strength, dry granulation tissue weight, hydroxyproline estimation and histopathology of the granulation tissue. Aqueous and methanol barks extracts promoted the wound healing activity significantly in all the wound models studied⁵⁰.

Curcuma longa Linn.

Curcuma longa Linn. belonging to family Zingiberaceae, commonly known as turmeric and haldi in Hindi. *Curcuma longa* has been reported to possess antibacterial, anti-fungal and anti-inflammatory activities. The part used are rhizomes and it contains curcumin (diferuloyl methane), turmeric oil or turmerol and 1,7-bis, 6- hepta-diene-3, 5-dione. Curcumin has potent anti-inflammatory and analgesic activities. Volatile oil isolated from *Curcuma longa* also exhibits antibacterial and potent anti-inflammatory activity. *Curcuma longa* also contains protein, fats, vitamins (A, B, C etc) all of which have an important role in wound healing and regeneration. Turmeric has been used for treating the wounds in the rats⁵¹.

Ocimum sanctum Linn.

Ocimum sanctum Linn. belonging to the family Labiatae, is a herbaceous plant commonly known as tulsi is found throughout the semitropical and tropical parts of India. Different parts of the plant are traditionally used in Ayurveda and Siddha systems for the treatment of diverse ailments like infections, skin diseases, hepatic disorders and as an antidote for snake bite and scorpion sting. The ether extract and essential oil of the leaves exhibited antibacterial activity against a number of bacterial species. A methanol extract and an aqueous suspension of *Ocimum sanctum* leaves were found to have anti-inflammatory, analgesic and immunostimulatory properties. The extract of *Ocimum sanctum* significantly increased the wound breaking strength in incision wound model. The extract treated wounds were found to epithelialize faster and the rate of wound

contraction was significantly increased as compared to control wounds. Significant increase in wet and dry granulation tissue weight, granulation tissue breaking strength and hydroxyproline content in dead space wound model was observed⁵².

Moringa oleifera Linn.

Moringa oleifera Linn. (Moringaceae) has been an ingredient of Indian diet since centuries. The leaves of the plant have also been reported for its anti-tumor, hypotensive, antioxidant, radio-protective, anti-inflammatory and diuretic properties. The aqueous extract was studied and it was found that there was significant increase in wound closure rate, skin-breaking strength, granuloma breaking strength, hydroxyproline content, granuloma dry weight and decrease in scar area was observed⁵³.

Sesamum indicum Linn.

Sesamum indicum Linn. (Pedaliaceae) is one of the oldest cultivated plants in the world that is mainly grown for its oil rich edible seeds. The seeds possess potent antioxidant effect due to the presence of sesamol. Traditionally, sesame seeds are used in the treatment of wounds, especially burn wounds. Seeds and oil treatment in dead space wound model, produced a significant increase in the breaking strength, dry weight and hydroxyproline content of the granulation tissue. The results suggest that *Sesamum indicum* seeds and oil applied topically or administered orally possesses wound healing activity⁵⁴.

Solanum xanthocarpum Linn.

Solanum xanthocarpum Linn. (Solanaceae) is a very prickly perennial herb and found in Southeast Asia, Malaya and tropical Australia. Stem, flowers and fruits are bitter and carminative, employed as anthelmintic, in indigestion, cough, asthma and pains in chest, being used in the form of a decoction and also prescribed for relief in burning sensation in the feet accompanied by vesicular watery eruptions. It has high concentration of solasodine, a starting material for the manufacture of cortisone and sex hormones and scientifically reported as antifungal, anti-spermatogenic, anti-androgenic, anti-nociceptive and hypoglycemic. The methanolic fruit extract was showed significantly wound healing property. The tensile strength of the healing tissue after treatment was also found to be significantly higher (37.5%) as compared to the control⁵⁵.

Lantana camara Linn.

Lantana camara Linn. (Verbanaceae), a shrub native of tropical America has completely been naturalized in many parts of India as an ornamental plant. The plant has abortifacient, antimalarial, anti-inflammatory and wound healing properties. The hydro-alcoholic extract and fresh juice of leaves have favoured wound contraction⁵⁶.



Helianthus annus Linn.

Helianthus annus Linn. is belonging the family Asteraceae, An ornamental annual herb, with erect, rough and hairy stem is common in Indian Gardens in swampy areas. In traditional medicine the plant is used by tribals for inflammation of eyes, sores, dysuria, colic, tiger bites and bone fractures. In a study the alcoholic extract of whole plant of *Helianthus annus* applied in the form of an ointment on the excised wound of rat led to a significant reduction in total healing period. This has been confirmed by histology where earlier appearances of fibroblasts were seen. Early appearance and higher accumulation of mucopolysaccharides has been stated as indicators of hastened repair⁵⁷.

Tridax procumbens Linn.

Tridax procumbens Linn. (Asteraceae) is a native of tropical America and naturalized in tropical Africa, Australia and Asia including India. Leaf of *Tridax procumbens* mainly contains crude protein, crude fiber (17%), soluble carbohydrate (39%) and calcium oxide (5%). The juice of the leaves of this plant is used by villagers to arrest bleeding from cuts and bruises in animals. This juice accelerates two phases of healing namely epithelization and collagenization however it retards scar formation and granulation⁵⁸.

Hydnocarpus wightiana

The oil of *Hydnocarpus* spp. (Achariaceae) has been used for several years as anti-leprosy drug and as an anti-

parasitic drug in the treatment of guinea worm infestation. The oil of *Hydnocarpus* spp. when given orally or administered topically helped to heal the wounds and gangrene faster in leprosy and diabetic patients. The wound healing effect of oil of *Hydnocarpus* spp. was studied with reference to collagenization and the strength of scar tissue. The drug treated group showed a significant increase in strength of scar tissues in the incision wound model and also increased the strength of collagen tissue and hydroxyl-proline content in the dead space wound model. *Hydnocarpus* oil administered orally promoted epithelization, but not wound contraction^{59,60}.

Lepidium sativum Linn.

Lepidium sativum Linn. (Cruciferae) was well recognized in European communities as *Herba Lepidii Sativi*, and its consumption had increased in the former Soviet Union and Western European countries as a source of vitamins, diuresis effect, a stimulant of bile function, and a cough reliever. In addition, this plant was used in the community of Saudi Arabia as an important element in Saudi folk medicine for multiple applications, but mainly in fracture healing. The roots of the plant, leaves, and their seeds were used traditionally, but the effect of the seeds on fracture healing was noticed publicly in folk medicine and has been reported in rats. The *Lepidium sativum* plant and seeds are well known in the community of Saudi Arabia and some other Arabic countries as a good mediator for fracture healing in the human skeleton⁶¹.

Table 1: Plants (alphabetical order) having wound healing activity

Botanical Name	Family	Part/ingredients used	Ref.
<i>Acacia catechu</i> Willd.	Mimosaceae	Crushed bark used topical on the wound.	62
<i>Acalypha indica</i> L.	Euphorbiaceae	Leaf of plant is taken orally to treat wounds.	63
<i>Achyranthes aspera</i> L.	Amaranthaceae	Latex of the plant applied on the wound.	62
<i>Adhatoda zeylanica</i> M.	Acanthaceae	The leaf is applied to wound and cuts.	64
<i>Agrimonia pilosa</i> Ledeb.	Rosaceae	Pounded whole plant is applied locally.	65
<i>Alstonia scholaris</i> R.Br.	Apocynaceae	The latex is applied to wounds and boils	64
<i>Anacardium occidentale</i> L.	Anacardiaceae	Fruit is taken orally to heal wounds.	63
<i>Areca catechu</i> L.	Arecaceae	Powder of Fruit was applied on the wound.	62
<i>Argemone mexicana</i> L.	Papaveraceae	Leaves and Latex used as topically on wound.	62
<i>Aristida setacea</i> Retz.	Poaceae	Paste of plant parts is applied to heal wounds.	63
<i>Barleria prionitis</i> L.	Acanthaceae	Crushed leaves applied on the wound.	62
<i>Begonia fallox</i> DC.	Begoniaceae	Paste of leaf & stem are applied to heal wounds.	63
<i>Betula alnoides</i> B.H.	Betulaceae	Bark paste is applied locally.	65
<i>Blepharis maderaspatensis</i>	Acanthaceae	Juice of leaf is applied topically to heal wounds.	63
<i>Boschniakia himalaica</i>	Orobanchaceae	Whole plant poultice applied.	65
<i>Brassica juncea</i> L.	Brassicaceae	Paste of crushed fruit was applied on the wound.	62
<i>Bryophyllum calycinum</i>	Crassulaceae	Juice of the leaf applied on the wound.	62
<i>Buxus wallichiana</i>	Buxaceae	Bark paste is applied locally.	65
<i>Calendula officinalis</i> L.	Asteraceae	Crushed flowers applied on the wound.	62
<i>Callicarpa arborea</i> Roxb.	Verbenaceae	Paste of the bark and juice is applied to cuts.	64
<i>Calotropis gigantea</i> L.	Asclepiadaceae	Drops of the stem latex are used to treat wounds	63
<i>Calotropis procera</i> Br	Asclepiadaceae	Latex and leaves was applied on the wound.	62
<i>Caryopteris odorata</i>	Verbenaceae	Wood paste applied as plaster.	65
<i>Cassia alata</i> L.	Caesalpiniae	Leaves of the plant applied on the wound.	62
<i>Cassia auriculata</i> L.	Caesalpiniae	Leaves and Bark usually applied on the wound.	62
<i>Chasalia curviflora</i> Wall.	Rubiaceae	Paste of root is applied topically to heal wounds.	63
<i>Chenopodium album</i> Linn.	Chenopodiaceae	Crushed leaves are applied locally.	65



Botanical Name	Family	Part/ingredients used	Ref.
<i>Cirsium sinense</i> CBC.	Asteraceae	The root is crushed and tied on the wounds.	64
<i>Cirsium verutum</i> Spreng.	Asteraceae	Root paste is applied on wounds.	65
<i>Cissampelos pareira</i> L.	Menispermaceae	Juice of leaf is applied topically to heal wounds.	63
<i>Cleome viscosa</i> L.	Cleomaceae	Paste of leaf is applied topically to heal wounds.	63
<i>Combretum flagrocarpum</i>	Combretaceae	The leaf juice is applied to wounds and cuts.	64
<i>Commelina benghalensis</i>	Commelinaceae	Juice of the stem is applied to heal wounds.	63
<i>Commiphora mukul</i> Engl.	Burseraceae	Bark exudates was applied on the wound.	62
<i>Curcuma domestica</i> V.	Zingiberaceae	The tuber is mashed and is applied on wounds.	64
<i>Curcuma longa</i> L.	Zingiberaceae	Paste of the rhizomes applied on the wound.	62
<i>Cyanotis villosa</i> Spreng.	Commelinaceae	Paste of stem is applied to heal wounds.	63
<i>Datura stramonium</i> L.	Solanaceae	Latex of the leaves was applied on the wound.	62
<i>Daucus carota</i> L.	Apiaceae	Juice of the root applied on the wound.	62
<i>Dendrophthoe falcata</i> L.f.	Loranthaceae	Paste of leaf and stem is applied to heal wounds.	63
<i>Diotacanthus albiflorus</i>	Acanthaceae	Paste of leaf is applied topically to heal wounds.	63
<i>Dodonaea viscosa</i> Linn.	Sapindaceae	Leaf paste with albumin applied as plaster.	66
<i>Dumasia villosa</i> DC.	Fabaceae	Whole plant parts are used to wash wounds.	63
<i>Eupatorium odoratum</i> L.	Asteraceae	The leaf is applied to wound and cuts.	63
<i>Euphorbia antiquorum</i> L.,	Euphorbiaceae	Latex from the stem is applied on burn injury.	63
<i>Euphorbia hirta</i> L.	Euphorbiaceae	Fresh latex is applied topically to heal wounds.	63
<i>Euphorbia pilosa</i>	Euphorbiaceae	Latex of plant applied locally.	65
<i>Ficus bengalensis</i> L.,	Moraceae	Leaf powder is applied topically to treat wounds.	63
<i>Ficus religiosa</i> L.	Moraceae	Aqueous extract of bark applied on the wound.	62
<i>Gelsemium elegans</i>	Loganiaceae	The leaf juice is applied to wounds and cuts.	64
<i>Ixora coccinea</i> L.	Rubiaceae	Flower's Decoction is applied to heal wounds.	63
<i>Jatropha gossypifolia</i> L.	Euphorbiaceae	Resin of the plant is used to heal wounds.	63
<i>Jatropha curcas</i> L.	Euphorbiaceae	Bark exudates was applied on the wound.	67
<i>Melastoma malabathricum</i>	Malastomataceae	Paste of bark and juice is applied to cure wounds.	64
<i>Mentha viridis</i> L.	Lamiaceae	Leaves paste was applied on the wound.	62
<i>Mikania micrantha</i> HBK	Asteraceae	The leaf juice is applied to wounds and cuts.	64
<i>Morinda pubescens</i>	Rubiaceae	Leaf paste is applied topically to heal wounds.	63
<i>Moringa oleifera</i> L.	Moringaceae	Leaves paste was applied on the wound.	62
<i>Murraya paniculata</i> Linn.	Rutaceae	Leaf paste with albumin applied as plaster.	66
<i>Nerium indicum</i> Mill	Apocyanaceae	Juice of the leaves was applied on the wound.	62
<i>Ophiorrhiza mungos</i> L.,	Rubiaceae	Paste of whole plant is applied to heal wounds.	63
<i>Pedilanthus tithymaloides</i>	Euphorbiaceae	Latex of the plant applied on the wound.	62
<i>Pinus roxburghii</i>	Pinaceae	Bark paste is applied locally.	65
<i>Polygonatum officinale</i> A.	Liliaceae	Root extract given orally.	65
<i>Pongamia pinnata</i> L.	Fabaceae	Seeds oil is applied topically on wounds.	63
<i>Pongamia pinnata</i> Vent.	Fabaceae	Juice of leaves of applied on the wound.	62
<i>Pothos scandens</i> L.	Araceae	Paste of leaf is applied topically on wounds.	63
<i>Psychotria flavida</i>	Rubiaceae	Root powder is applied topically to treat wounds.	63
<i>Rubia cordifolia</i> L.	Rubiaceae	Bark and Root mostly applied on the wound.	62
<i>Rungia repens</i> L.	Acanthaceae	Paste of whole plant is applied on wounds.	63
<i>Scoparia dulcis</i> L.,	Scrophulariaceae	Paste of leaf applied to heal wounds.	63
<i>Sida acuta</i> Burm.F.	Malvaceae	Leaf paste with albumin applied as plaster.	66
<i>Smilax zeylanica</i> L.,	Smilacaceae	Rhizome is taken orally to heal wounds.	63
<i>Taxus wallichiana</i> Zucc.	Taxaceae	Bark paste is applied locally.	65
<i>Terminalia chebula</i>	Combretaceae	Triturated leaves is applied on wound.	62
<i>Thespesia populnea</i> Soland	Malvaceae	Fruit of plant in crush used as wound healing.	62
<i>Trichosanthes tricuspidata</i>	Cucurbitaceae	Juice of the fruit used as wound healing.	62
<i>Tridax procumbens</i> L.	Asteraceae	Mostly leaves of this plant applied on the wound.	62
<i>Ulmus wallichiana</i> Planch.	Ulmaceae	Bark paste is applied locally.	65

CONCLUSION

Wound healing is a biological process that starts with trauma and ends with scar formation. The present review clearly revealed that nature provides huge number of plants that show significant wound healing activities. These natural agencies are rich target for the development of alternatives to synthetic drugs. The

combination of traditional and modern knowledge can produce better drugs for wound healing with fewer side effects. However, there is a need for scientific validation, standardization and safety evaluation of plants of the traditional medicine before these could be recommended for healing of the wounds.



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