https://doi.org/10.51470/IJNS.2024.01.01.1

Crossref

Regd.No. 114/2017

International Journal of Nature Science (IJNS)

Estd:2024

From Forest to First Aid: A Review of Western Ghats Plants for Wound Healing

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Article History

Volume:1, Issue:1, 2024

Received: 17th January, 2024

Accepted: 20th January, 2024

Published: 30th January, 2024.

doi.org/10.51470/IJNS.2024.01.01.1-14

Abstract: *India has been blessed with immense varieties of plants and most of them are found in the Western Ghats. There is a vast number of medicinal plants are found in the Western Ghats, which are widely used by the indigenous people. Medicinal plants have an essential role in healing and managing wounds. The bioactive compounds found in plants are responsible for its wound healing activities. The wound healing properties of the medicinal plants are influenced by the anti- microbial, anti-inflammatory, and anti-oxidant properties of plants. The selected medicinal plants possess remarkable inhibitory activity against the different bacterial as well as fungal species. Besides that, the results of the in-vitro studies have also reported the significant anti-inflammatory, anti-oxidant, and wound healing properties of those medicinal plants. Hence, the medicinal plants found in Western Ghats will be promising source for treating and healing the different types of wounds. The present review aims to document the scientific reports for the anti-microbial, anti- inflammatory, anti-oxidant and wound healing potency of some of the medicinal plants of Western Ghats.*

Keywords: *Medicinal plants, Wound healing, Anti-microbial, Anti-inflammatory, Anti-oxidant*

Authors citation: Purushothaman.T et.al., From Forest to First Aid: A Review of Western Ghats Plants for Wound Healing.Int.J.Nat.Sci.Vol.1(1). 2024.Pp:1-10. https://doi.org/10.51470/IJNS.2024.01.01.1

INTRODUCTION

The role of medicinal plants in human life is indispensable from the olden days, which are commonly used by indigenous people. But, 60-80% of worldwide population are still depends on the plant and derived components for treating diseases. India has been enriched with broad varieties of medicinal plants and most of them are found in Western Ghats (Dar, R. A et al., 2017). So, these medicinal plants are extensively used by the various tribal communities residing in and around Western Ghats (Jeyaprakash, K et al., 2011).

The medicinal plants play a pivotal role in treating and healing all types of wounds since ancient times. The bioactive components present in the plants forms the basis for the traditional as well as modern medicines. Majority of the available medicines are derived from plants, via the isolation of biologically active compounds. There are several scientific evidence are available in corresponding with healing of wounds using medicinal plants (Alam, G et al., 2011)

The plants will initiate the healing mechanism in a natural way and it is cost-effective solution than the synthetic medicines. Moreover, it exhibit lesser side-effects in comparison with chemical substances (Sharma, P et al., 2020). Considering these advantages, we have attempted to explore the wound healing activities of some medicinal plants found in the Western Ghats. Hence, this review provides the scientific evidence for the anti-microbial, anti-inflammatory, anti-oxidant and wound healing activity of selected medicinal plants of Western Ghats.

MECHANISM OF WOUND HEALING

The wound healing is the highly complex process which involves numerous events for the restoration or re-epithelialization of the impaired skin (Han, G., & Ceilley, R. 2017). It is a pivotal process, where the varieties of cells and its products synchronize to initiate the mechanism of wound healing. The duration of wound healing will differ depending on the types of wounds. The mechanism of wound healing begins immediately after the injury and it may continue for varied time period (Rawat, S et al., 2012). There are different phases involved in the wound healing mechanism such as

- Hemostatic phase
- Inflammatory phase
- Proliferative phase
- Remodeling phase

Hemostatic phase:

The mechanism of wound healing begins with the hemostatic phase, which happens immediately after the injury of the skin. The platelet gets aggregated and thereby stimulating the cascade of events like production of thrombin. The thrombin aids in the conversion of fibrinogen to fibrin and the fibrin along with the platelets forms the blood clot in order to control and stop the hemorrhage (Wilkinson, H. N et al., 2020).

Inflammatory phase:

The inflammatory phase is considered the over-lapping phase of the hemostatic phase. This phase may last for 24 hours to 2 weeks. It is characterized by vasoconstriction, secretion of pro- inflammatory agents, neutrophils and the aggregation of platelets for the induction of phagocytosis (Maheswary, T et al., 2021).

Proliferative phase:

The proliferative phase is initiated at the end of the inflammatory phase. The proliferation of fibroblast aids in the deposition of collagen and the contraction of wounds, which ultimately results in the reduction of wound size. The epithelial cells start to arrange in the normal pattern on the wounded area and followed by the angiogenesis and re-establishment of cellular network takes place. This phases ends with the formation of granulation tissue which promotes the closure of wounds (Sinno, H et al., 2013).

Remodeling phase:

The remodeling phase may take days to several months. The remodeling of dermis, epidermis, nerves, and the myofibres found in the skeletal muscle happens in the formation of functional tissue. The granulation tissue gets replaced by the collagen and so it gets converted to the scar with low tensile strength (Cañedo-Dorantes, L et al., 2019)

ROLE OF PLANTS IN WOUND HEALING:

The traditional system of healing wounds, majorly employs the natural resources and now-a- days it has gained broad range of attention among the world-wide population (Aleksandra Shedoeva et al., 2019). The Plants has an essential role in healing of various wounds from the ancient times. Various plants derived extracts have been employed in folk medicine for curing the distinct types of epithelium and skin wounds. These herbal products stimulate the rapid wound healing by accelerating the blood clotting mechanism and preventing infections (Dhanalekshmi, U et al.,

2010). The plants are regarded as the most promising agent for wound healing as it repairs the impaired skin in the natural way (Kumarasamyraja, D et al., 2012). The phytochemicals or secondary metabolites present in the plants aids in potent therapeutic activity. The medicinal plants serve as the natural repository of novel compounds with numerous biological activities (Nagori, B. P et al., 2011). It is estimated that about 73% of currently using pharmaceutical products are

derived from the natural sources like plants (Aleksandra Shedoeva et al., 2019). The utilization of plant-based medicines results in lesser side-effects and also it is cost-effective compared to other sources of medicines. Numerous scientific studies have evidenced the wound healing activity of various plant extracts along with the antimicrobial activity (Bahramsoltani et al., 2014). Some of the medicinal plants in Western Ghats used for healing wounds are listed below.

Table 1: List of some medicinal plants in Western Ghats for healing wounds

NAME OF THE PLANT	FAMILY	COMMON NAMES	NATURAL HABITAT
Aegle marmelos	Rutaceae	Bael, bengal quince, Japanese bitter orange, stone apple	India, Bangladesh, Sri Lanka, Nepal, Thailand, and Malaysia
Aerva lanata	Amaranthaceae	Knotgrass	India, South Africa, Madagascar, Saudi Arabia
Allium sativum	Amaryllidaceae	Garlic	Central Asia, Siberia , Northeastern Iran
Aloe barbadensis Miller	Asphodelaceae	Aloe vera,burn plant, medicinal aloe	Barbados, Trinidad, Mexico, Nigeria, India and Tobago
Anethum graveolens	Apiaceae	Dill	India, Malaysian archipelago and Japan.
Azadirachta indica	Meliaceae	Neem, nimtree, Indian lilac	India, Nepal, Pakistan, Bangladesh, Sri Lanka, and Maldives
Calotropis gigantea	Apocynaceae	Milkweed, swallow-wort	India, Cambodia, Vietnam, Bangladesh, Indonesia, Malaysia, the Philippines, Thailand, Sri Lanka, China, Pakistan, Nepal, tropical Africa

Catharanthus roseus	Apocynaceae	Madagascar periwinkle,graveyard plant	India, Madagascar
Curcuma longa	Zingiberaceae	Turmeric	Asia, India, China

HEALING PROPERTIES OF PLANTS

The wound healing activity of the plants mainly relies on pharmacological activities like anti-microbial, antioxidant, and anti-inflammatory. Then the phytoconstituents such as alkaloids, flavonoids, tannins, terpenoids, saponins, essential oils, and carbohydrates contribute to the synthesis of collagen, angiogenesis, cellular proliferation, and re-epithelialization and remodeling tissues. This ultimately results in the contraction and healing of wounds (Derakhshanfar et al.,2019).

So, the phytochemicals aid the healing of wounds via anti-microbial, antioxidant, and anti- inflammatory properties. Some of the plant extracts and their bioactive compounds act as potent free radical scavengers, which ultimately results in enhanced wound healing (Shetty et al., 2008; Geethalakshmi et al., 2013).

Table 2: Wound healing activity of selected medicinal plants

NAME OF PLANT	PARTS	EXTRACT	METHOD	CONCENTRATION	% OF CONTRACTION AND DAYS	REFERENCE
Aegle marmelos	Leaves	Methanol	Excision wound in male albino Swiss mice	Topical application in the	99.93±0.05 % (12th	Arunachalam *et al.,* 2012
Aerva lanata	Leaves	Ethanol	Excision wound, Incision wound, and Dead space	300mg/kg	97.24±0.01 % (14thday)	Devi *et al.,* 2009
Azadirachta indica	Leaves	Ethanol	Linear incision wound in Albino rabbits			Munir *et al.,* 2021
Allium sativum	Bulb	Ethanol	Excision wound model in swiss albino mice model	10%(w/w)	100% (16th day)	Zuber *et al.,* 2013
Aloe barbadensis Miller	Gel	Aqueous	Excision wound infemale Sprague-Dawley rats	96.4%	99.19% (16th day)	Yadav *et al.,* 2012
Anethum graveolens	Aerial parts	Essential Oil	MRSA-induced wound in BALB/c mice model	4%	100% (16th day)	Manzuoerh *et al.,* 2019
Azadirachta indica	Leaves	Ethanol	Excision model in Albino and Wister mice model	5%w/w	88.65% (15th day)	Babu *et al.,* 2016
Calotropis gigantea	Root bark	Ethanol	Excision wound	50mg /day	98.96±0.13 % (20th day)	Deshmukh *et al.,* 2009
Catharanthus roseus	Flower	Aqueous	Excision wound model in albino rats		91.27±3.45 % (18th day)	Satish *et al.,* 2021
Curcuma longa	Rhizomes	Ethanol	Excision wound in male wistar rats model	Topical application	100%(21st day)	Charde *et al.,* 2010

Anti- microbial effects:

The anti-microbial activities are also largely influencing the process of wound healing. The phytochemicals present in the extracts with anti-microbial effects help in managing the infections caused by various microbes in acute and chronic wounds (Rex et al., 2018). Usually, the wounds are vulnerable to infections and so the existence of micro-organisms delays the process of healing. So, the anti-microbial substances restraints the infections and also promotes rapid wound healing (Vittorazzi et al., 2016). A low rate of infections in the wounds leads to the production of numerous neutrophils, which fight against the microbes and also helps in averting the desiccation of tissues as well as necrosis (de la Secreción, 2012).

Table 3: Anti-microbial properties of selected medicinal plants

PLANT	PARTS	EXTRACTS	CONCENTRATION	TEST ORGANISMS	ZONE OF INHIBITION/ MIC	REFERENCE
Aegle marmelos	Fruits	Ethanol	200 µg/ml	*S. epidermis*	12.6±0.35mm	Gupta *et al.,* 2018
				S.aureus	10.3±0.41mm	
				E. coli	14.6±0.52mm	
				P.aeruginosa	16.1±0.86mm	
				C.albicans	8.6±0.24mm	
Aerva lanata	Leaves	Ethanol	900 µg/ml	*E. coli*	14.05mm	Kairamkonda *et al.,* 2017
				P.vulgaris	8.04mm	
				B.subtilis	12.08mm	
				B.pumilus	4.28mm	
				C.albicans	9.56mm	
				F.oxyparum	13.56mm	
				C.falcatum	13.76mm	
Allium sativum	Clove	Aqueous	100µl	*B. cereus*	21.7±1.2mm	Phan *et al.,* 2019
				L. monocytogenes	33.9±1.2mm	
				S. aureus	19.1±1.1mm	
				E.coli	15.8±0.7mm	
				R.mucilaginosa	27.1±0.4mm	
				C. albicans	23.5±3.7mm	
Aloe barbadensis Miller	Leaves	Methanol	100mg/ml	*S. marcescens*	11.00±1.00m m	Dharajiya *et al.,* 2017
				B. cereus	12.33±0.57m	
				P.aeruginosa	08.83±0.76m	
				E.coli	10.33±0.57m	
				A.oryzae	08.6±0.57mm	
	Sap	Acetone	6.25µg/ml	*E. coli*	31mm	Abakar *et al.,*
				P.aeruginosa	31mm	

				B.subtilis	30mm	
				S.aureus	30mm	2017
				C.albicans	20mm	
				A.niger	18mm	
Anethum	Dried	Essential oil	10 µL	*E.faecalis*	8.7±0.5mm	Tanruean *et*
				K. pneumonia	11.3±0.5mm	
Azadiracht	Leaves	Chloroform	8mg/ml	*Salmonella sp*	8.2mm	Akoh *et al.,*
				P.mirabilis	2.2mm	
aindica				*S.aureus*	6.0mm	2021
				S.pyogenes	4.0mm	
	Twigs	Methanol	500 mg/ml	*S.mutans*	20mm	Adyanthaya
				S.salivarius	10mm	
				S.mitis	16mm	*et al.,* 2014
				Lactobacillus sp	22mm	
				P.intermedia	20mm	
				C.albicans	10mm	
Calotropis	Latex	Aqueous	100µl	*S.aureus*	30±1mm	Kumar *et al.,*
				Bacillus cereus	16±1mm	
gigantea				*E. coli*	24.6±0.5mm	2010
				Candida krusei	13.6±0.5mm	
Catharant	Leaves	Ethanol	100mg/ml	*E. coli*	11mm	Khalil *et al.*,
				S. aureus	15mm	
hus roseus				*C.albicans*	12mm	2012
Curcuma	rhizomes	Methanol	1mg/ml	*B.subtilis*	14.00±0.70m	Ikpeama *et*
					...	
longa				*P.aerigunosa*	15.00±0.80m	*al.,* 2015
					...	

				S.aureus	7.00±1.41mm	
				E. coli	9.00±0.14mm	
				S.faecalis	12.00±0.14mm	
				Micrococcus lutes	13.00±0.70mm	
				A.niger	20.00±0.71mm	
				P.citrinin	16.00±0.90mm	

Antioxidant effects:

The antioxidant properties play a vital role in the wound healing effects. The plant extracts or plant derived compounds with an increased level of antioxidants has exhibited significant wound healing activity (Lordani et al., 2018). Reactive oxygen species (ROS) are produced against the invading bacteria at the injured site. But, the existence of an increased number of ROS will affect the process of wound healing and so the plant antioxidants help in reducing the excess ROS and the adverse effects. Hence, the plant extracts and bioactive compounds with remarkable radical scavenging activity will be a potent source for wound healing (Süntar et al., 2012). The antioxidant capabilities of medicinal plants in traditional medicine for wound healing were listed below.

Table 4: Antioxidant activities of selected medicinal plants

PLANT	**PARTS**	**EXTRACT**	**CONCENTRATION**	**METHODS**	**RESULTS IC50 / % OF INHIBITION**	**REFERENCE**
Aegle marmelos	Leaves	Aqueous	100µl	DPPH scavenging	132.1µg/ml	Reshma and Brindha, 2014
			200µl	Reducing power activity	17.84 µg/ml	
				Superoxide anion scavenging activity	24.89 µg/ml	
Aerva lanata	Whole plant	Ethanol	75µg/ml	DPPH method	59.40±0.93%	Krishnamoorthi, 2015
Allium				DPPH		

sativum	Bulb	Chopped	1ml	method	21.69±3.22%	Queiroz *et al.,*
Aloe barbadensis Miller	Gel	Ethanol	400µg/ml	DPPH method	51.09±0.338 %	Gorsi *et al.,*
Anethum graveolens	Leaves	Aqueous	1mg/ml	DPPH method	86%	Oshaghi *et al.,* 2016
				Superoxide scavenging activity	96%	
				Hydrogen peroxide Scavenging activity	96%	
Azadirachta indica	Leaves	Methanol	500 µg	DPPH method	71.23%	Pokhrel *et al.,* 2015
Calotropis gigantea	Flowers	Chloroform	1mg/ml	DPPH method	89.27±0.01µg /ml	Rajamohan *et al.,* 2014
Catharanthus roseus	Leaves	Methanol	800µg	DPPH method	81.70%	Patharajan and BalaAbirami, 2014
Curcuma	Rhizom	Juice	200 µl	DPPH	64.6 ± 2.4%	Maizura *et*

Anti-inflammatory effects:

The plant extracts with anti-inflammatory agents are also considered to be effective in the wound healing process. So, the phytochemicals or the secondary metabolites can act as a modulator to reduce inflammation and encourages the epithelization of impaired skin (Shukla i 2019). The inflammation may also affect the rate of wound healing. The phyto-compounds have the tendency to diminish the inflammation and its related conditions via modulating the inflammatory conditions (Ghuman et al., 2019). The anti-inflammatory properties of selected medicinal plants are enlisted below.

Table 5: Anti-inflammatory activities of selected medicinal plants

PLANT	PARTS	EXTRACT	CONCENTRATION	METHODS	RESULTS	REFERENCE
Aegle marmelos	Leaves	Aqueous	100µ1	Inhibition of protein denaturation	95.64µg/ml	Reshma and Brindha, 2014
				Membrane stabilization activity	405.6 µg/ml	
				Inhibition of proteinase activity	75.45 µg/ml	
Aerva lanata	Whole plant	Aqueous	800µg/ml	Membrane stabilization method	104.4%	KV et al., 2021
				Protein denaturation method	129.3%	
Allium sativum	Bulb	Methanol	20mg/kg	Carrageenan paw edema in male wistar rat model	90.9%	Nithya, 2021
Aloe barbadensis Miller	Leaves	Aqueous	100 mg/kg	Formalin Induced Hind Paw Oedema in wistar rats	41.77%	Egesie et al., 2011

				Acetic Acid-Induced Abdominal Writhing Test	68.06%	
Anethum graveolens	Leaves	Essential oil	45.0mg/mL	In-vitro model of lipopolysaccharide (LPS)-stimulated macrophages	82.0±0.0%	Kazemi et al., 2015
Azadirachta indica	Bark	Ethanol	500mg/kg	Carrageenan induced rat paw inflammation	22.22±0.30%	Emran et al., 2015
Calotropis gigantea	Leaves	Ethanol	200mg/kg	Inhibition of albumin denaturation technique	78.57%	Va et al., 2010
Catharanthus roseus	Whole plant	Ethanol	300mg/ml	Membrane stabilization method	82.5±0.05%	Vinay et al., 2014
				Albumin denaturation method	83.31±0.06%	
				Heat induced hemolysis	88.82±0.06%	
Curcuma Longa	Leaves	Essential oil	4mg/ml	DPPH Radical Scavenging Assay	65%	Priya et al., 2012
			3.3mg/ml	ABTS Radical scavenging assay	85%	
Linum Usitatissimum	Seeds	Ethanol	500mg/ml	DPPH Radical Scavenging Assay	82.53±0.17954%	Amin & Thakur, 2014
				Scavenging of Hydrogen Peroxide	86.61±0.02404%	

CONCLUSION: The present review has highlighted the wound healing potency of some of the medicinal plants found in the Western Ghats. The wound healing properties of medicinal plants are influenced by their anti-microbial, anti-inflammatory as well as antioxidant activities. Therefore, many reports are also enlisted in this review for demonstrating the anti-microbial, anti-inflammatory as well as anti-oxidant efficacy of the

selected medicinal plants. So, the above-listed evidence indicated that the selected medicinal plants possess significant wound healing properties and it also promotes the healing mechanism via a natural process. Hence, the isolation of bioactive compounds from these

selected medicinal plants will benefit the development of novel medicines. But, there are still many unexplored medicinal plants, which are used by the indigenous people for wound healing. So, extensive research should be carried out to identify and validate those plants for their therapeutic benefits.

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