



# *Tridax procumbens*: A Weed Turned Wonder - Exploring Its Therapeutic Versatility and Pharmacological Promise

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## Abstract:

*Tridax procumbens*, a globally prevalent weed and an integral part of traditional Ayurvedic medicine, exhibits diverse pharmacological properties due to its rich phytochemical composition. This review consolidates the therapeutic potential of *T. procumbens* across various domains, highlighting its antimicrobial, antioxidant, anti-inflammatory, wound healing, hepatoprotective, antidiabetic, anticancer, anti-ulcer, analgesic, antimalarial, hair growth-promoting, and neuroprotective activities. The plant's bioactive compounds, including alkaloids, flavonoids, tannins, glycosides, sterols, polyphenols, and vitamins, contribute to its multifunctional applications.

The antimicrobial activity is particularly noteworthy, targeting various bacterial strains, while its antioxidant properties, linked to phenolic compounds, play a crucial role in mitigating oxidative stress and facilitating wound healing. Anticancer studies reveal significant tumour-suppressive effects, particularly in breast and prostate cancer models. Additionally, *T. procumbens* demonstrates hepatoprotective effects by reducing oxidative stress and promoting liver cell regeneration. Its anti-inflammatory and analgesic effects are mediated through molecular pathways involving COX-2 and TNF- $\alpha$ .

Despite these promising results, most studies are limited to in vitro or preclinical models. Further research is required to elucidate detailed molecular mechanisms, optimize bioactive compound extraction, and evaluate clinical efficacy through human trials. Additionally, the development of novel drug delivery systems and standardized formulations can enhance its therapeutic potential and market viability.

This review underscores the need for advanced pharmacological investigations and sustainable utilization of *T. procumbens*. With its extensive pharmacological profile and promising therapeutic potential, *T. procumbens* emerges as a valuable candidate for drug discovery and development, offering opportunities for integration into modern medicine.

## Introduction: -

For centuries, nature has been a prolific source of medicinally active compounds, with numerous substances extracted from natural origins. Medicinal plants have long been regarded as a valuable and reliable resource for treating human diseases and ailments due to their diverse therapeutic components. Among such plants is *Tridax procumbens*, an annual or perennial herb (15–40 cm tall) native to Central and South America, now widely adapted to various regions across the globe, including India, where it thrives in diverse geographical and subtropical conditions. Commonly known as “cotton buttons,” *Tridax procumbens* belongs to the family Asteraceae (or Compositae) and shares its genus with species like *T. balbisioides* and *T. trilobata*.

This plant is globally distributed and grows abundantly in various Indian states, where it has been traditionally used as a domestic remedy for numerous ailments. Phytochemical studies have revealed the presence of flavonoids (such as catechins and flavones), alkaloids, tannins, saponins, and carotenoids in *Tridax procumbens*. It has a rich history in Indian traditional medicine, being utilized for wound healing, antifungal, anticoagulant, and insect-repellent properties. Additionally, it is employed to treat infectious diseases and diarrhoea.

*Tridax procumbens* exhibits a wide range of pharmacological properties, including immunomodulatory, antioxidant, anti-hepatotoxic, analgesic, antidiabetic, anti-inflammatory, antifungal, and antimicrobial activities. The plant has also been validated for its efficacy in addressing conditions such as wound healing, dysentery, epilepsy, hypertension, hepatotoxicity, haemorrhage, and metabolic syndrome. Its conventional applications for wound healing, antimicrobial effects, and insect-repellent properties are recognized globally, including across the Indian subcontinent. Leaf extracts of *Tridax procumbens* are particularly noted for their effectiveness in treating various infectious skin diseases.

This well-known Ayurvedic remedy is also used to manage heartburn, gastritis, and liver disorders, reflecting its hepatoprotective capabilities. The therapeutic potential of *Tridax procumbens* is attributed to its secondary metabolites, which play a crucial role in the plant's defence mechanisms and pharmacological efficacy.

This review underscores the importance of *Tridax procumbens* L. by highlighting its pharmacognosy attributes, traditional uses, and pharmacological actions. The evidence suggests that this species offers a safe, effective, and affordable solution for managing various ailments, particularly in tropical regions where it is native and widely distributed. Its extensive pharmacological spectrum positions it as a highly beneficial medicinal plant for human health.

**Keywords:-***Tridax procumbens* L., antioxidant, anti-hepatotoxic, anti-inflammatory, wound healing.

For generations, people across the globe have relied on home remedies, traditional healers, and ancestral medical knowledge to address their health and well-being. Various traditional systems of medicine—such as Ayurveda, Siddha, Unani, and the Chinese system—have served as rich sources for the identification, collection, and development of bioactive compounds from natural surroundings. The role of nature as a provider of medicinal compounds dates back to ancient civilizations, with numerous drugs being derived from natural sources over millennia. *Tridax procumbens* was first documented by Linnaeus in his publication in 1753, underscoring the longstanding significance of medicinal plants.

Herbal medicine continues to play a pivotal role in global healthcare, addressing approximately 80% of the healthcare needs of the global population. According to the *General Guidelines for Methodologies on Research and Evaluation of Traditional Medicine* (2001), over 65% of people worldwide—especially in rural areas of developing countries—depend on traditional medicine for primary healthcare. It is estimated that between 20,000 and 35,000 plant species are utilized globally in the development of pharmaceuticals, nutraceuticals, and cosmetics, particularly by diverse ethnic communities.

Recently, herbal remedies and plant-derived extracts have regained significant attention due to their affordability, accessibility, and perceived safety profile. These natural products are being increasingly considered for managing chronic diseases, addressing side effects of conventional treatments, and supporting preventive healthcare measures. Currently, various formulations based on *Tridax procumbens* are commercially available, reflecting the plant's broad therapeutic potential.

Notably, approximately 40% of modern medicines are derived from nature and traditional knowledge, including iconic examples such as aspirin, artemisinin, and treatments for childhood diseases. The integration of emerging technologies, such as artificial intelligence, is transforming conventional healthcare by enhancing research and innovation in traditional medicine. AI-driven approaches offer revolutionary potential for analysing traditional practices, enabling deeper insights into their mechanisms and efficacy.

Research on traditional medical systems and plant-based products is gaining momentum globally, fuelled by their growing popularity and demand. This expansion has led to a significant increase in data availability, which is essential for evaluating the efficacy, safety, and therapeutic potential of these remedies. Ongoing studies in this domain present a promising future, bridging the gap between historical knowledge and modern scientific advancements to create effective, evidence-based solutions for healthcare.

### Morphology:-

*Tridax procumbens* is a herbaceous perennial plant that can grow up to 40 centimetres in height and exhibits a spreading growth habit. It is a small green plant, typically ranging from 15 to 40 cm tall, with roots developing at the nodes. The plant's stems arise from a woody base, are covered with fine hairs, and bear oblong to lanceolate leaves with petioles measuring 4 to 30 mm in length.

The plant produces two distinct types of flowers: ray florets and disk florets. The ray florets exhibit basal placentation and are tubular at the base, with light yellow or creamy white ligules measuring 2.5–5 mm in length and 2–5 mm in width. The disk florets are prominently yellow, adding to the plant's characteristic appearance.

The fruit of *T. procumbens* is a rigid achene with stiff hairs and features a feathery plume at one end, resembling the appearance of white papaya seeds. The calyx is represented by scales or pappus, aiding in seed dispersal. The seeds possess a dangling endosperm but lack a developed embryo. This combination of structural and reproductive features contributes to the plant's adaptability and widespread distribution.

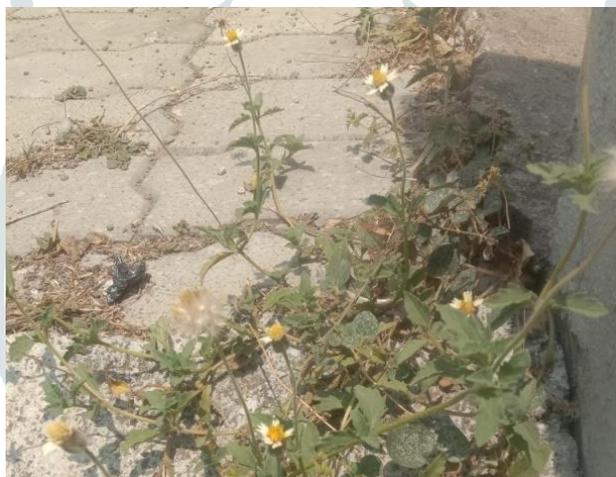


Figure 1: Tridax's entire plant

*Tridax procumbens* is a prostrate herbaceous flowering plant that grows up to 40 cm high. It is covered with erect stiff hairs, generally more scattered toward the base and attenuated toward the top. The root has a taproot system. It is native to tropical regions of America and widely spread as a weed all over the world. It is an annual species, especially weed which is propagated by seeds



Figure 2: Leaves of Tridax procumbens

Leaves of *Tridax procumbens* are opposite, simple, carried by a petiole, 1-2 cm long. They are thick, soft and dark green. Lamina is oval to lanceolate, approximately 2-6 cm long and 2-5 wide and base is attenuated in corner and with strongly and irregularly serrated margin. Leaves of *Tridax* show reticulate venation. Leaves are toothed and generally arrowhead-shaped. *Tridax procumbens* belongs to family Asteraceae which are included in kingdom plantae.



Figure 3: Flowers of *Tridax procumbens*

*Tridax procumbens* flowers have white rays and yellow disk flowers. They are about 0.4 to 0.6 inches wide, and held on a 4-12 inches long stock. Flowering occurs in spring season. Inflorescences in solitary capitulum, held by peduncle, 10-30 cm long abundantly hispid. The bract of the involucre is arranged in 2 rows. They are oval to lanceolate, 5 mm long, pubescent and green. Florates are yellow in color, tubulate bisexual which are present at center of capitulum and within florates there are membranous scales are present.

Table 1: Morphological characteristics of *Tridax procumbens*

Plant part	Characteristics
stem	Crawling at the bottom, growing branches, pilose (densely hairy), sub-erect, or trailing above
Leaf	oppositely directed, pinnate configuration, ovate in shape, 1 to 2 inches (2.5 to 5 cm) in length
Flowers/Inflorescences	Heads are bisexual, pentamerous, and actinomorphic solitary with yellowish numerous tubular-campanulate involucre of disc floret per head, 1.2-1.5cm across. The peduncle is 10-30 cm long.
Calyx	Characterized with scales, reduced to pappus.
Fruit	Characterized with scales
Seed	The plant seeds have a pendulous embryo so there is no endosperm
Root	Taproot system

Table 1: Taxonomical categorization of *Tridax procumbens*

Kingdom	Plantae
Division	Tracheophyta
Class	Magnoliopsida
Order	Asterales
Family	Asteraceae
Genus	<i>Tridax</i>
Species	<i>Tridax procumbens</i> L.

Table 2:- Common names

Language	Name
English	<i>Tridax</i> daisy
Hindi	Ghamra
Marathi	Kambarmodi
Telugu	Gaddichemanthi
Kannada	Jayanthi
Tamil	Vettukaayapoondur
Sanskrit	Jayanthi

Table 3: Traditional uses and plant preparation

Location	Preparation/extract	Plant ailment uses	References
India	Leaves: dried and other herbs ingested orally, juice	Diabetes, insect-repellent, is used to treat diarrhea and to help check for hemorrhages, as well as hair loss. Jaundice, healing of wounds, inflammation	Pareek et al., 2009, Policegoudra et al., 2014; Saraf et al., 1990, Saraf and Dixit, 1991, Rajendran et al., 2003, Taddei and Rosas-Romero, 2000, Yabesth et al., 2014; Pardeshi and Bhiungade, 2016 <sup>i, ii</sup>
Africa	Whole plant: blending with other herbs adding salt and water	Treating mastitis in livestock <sup>iii</sup>	Byavu et al., 2000
Ghana	Decoction with <i>Phyllanthus amarus</i>  Aqueous extract	Anti-malarial, antibacterial, wound-healing  Anti-plasmodial activity <sup>iv</sup> .	(Koram, 2014)  Appiah-Opong et al., 2011, Komlaga et al., 2015
Nigeria	Whole plant: dried	Fever, Typhoid fever, cough, backache, stomach ache, diarrhea, epilepsy <sup>v</sup>	Soladoye et al., 2013. Mann et al., 2003
Togo	Leaves: dried	Dressing wounds, pain, malaria, and abdominal and gastric mycosis <sup>vi</sup>	Agban et al., 2013

<b>Guatemala</b>	Leaves: poultice, dried infusions Stems: dried	Reduce inflammation, gastrointestinal and respiratory infections, high blood pressure, diabetes <sup>vii</sup>	Pöll, 2005, Giovannini et al., 2016
	Leaves: Juice	Anemia, colds, inflammation, hepatopathy, vaginitis, stomach pain, diarrhea, mucosal inflammation, skin infections, bleeding. <sup>viii</sup>	Caceres et al., 1998; Taddei and Rosas- Romero, 2000
	Whole plant: dried	Protozoal infections, treatment of chronic ulcers caused by leishmaniasis, gastrointestinal disorders <sup>ix</sup>	Berger et al., 1998. Martín-Quintal et al., 2009; Gamboa-Leon et al., 2014 Ebiloma et al., 2017

## Phytochemistry:

A preliminary phytochemical screening and quantitative test for the presence of phenols, tannins, flavonoids, alkaloids, terpenoids, anthraquinones, steroids, and saponins were analyzed using standard test protocols. These phytochemicals were identified by the characteristic color change using standard procedure. A significant number of investigations have been conducted on the phytochemical characteristics of *Tridax procumbens*. For example, anthraquinones, anthrones, flavonoids, and steroids are found in relative amounts in the leaves. Although the compounds have been identified, the exact bioactive compounds responsible for the medicinal properties are still unknown. Many of the compounds identified have unknown metabolic pathways, and several bioactive compounds may act in conjunction to elicit medicinal properties.

**Table 4:- Preliminary phytochemical evaluation of methanol extracts of *Tridax procumbens***

Phytochemical constituents	Test	Result
Phenol	Phenol	(+)
Flavonoids	Shinoda	(+)
	NaOH	(-)
Tannins	Lead acetate	(+)
	Gelatin	(+)
Saponins	Foam	(+)
	Hemolysis	(+)
Alkaloids	Iodine	(+)
	Wagner's test	(-)
Steroid	Acetic anhydride test	(+)

(+) = Present; (-) = Absent

### Tests for Phenols:

**Phenol Test:** The development of a vivid color following the addition of 0.5 ml of FeCl<sub>3</sub> solution (w/v) to 2 ml of the test solution signified the presence of phenolic compounds.<sup>x</sup>

### Test for Flavonoids:

**NaOH test:** A volume of 2-3 ml of the extract, along with several drops of sodium hydroxide solution, was introduced into the test tube. The emergence of a vivid yellow hue, which did not persist as colorless following the addition of a few drops of dilute HCl, suggested the absence of flavonoids.<sup>xi</sup>

### Shinoda Test:

In a test tube, 2-3 ml of extract was combined with Magnesium metal, followed by the gradual addition of concentrated Hydrochloric acid (HCl) drop by drop. The appearance of a purple color signified the presence of flavonoids.<sup>xii</sup>

### Test for Tannins:(Gelatin Test)

Gelatin solution was added to the extract (gelatin dissolves immediately in warm water). A white precipitate is generated since the extract contains Tannin, demonstrating the presence of Tannin in the extract.

Lead acetate test: A few drops of 10% lead acetate solution were added to 5 milliliters of extract. The yellow-to-crimson-red precipitate is brought about by the presence of Tannin in the extract.<sup>xiii</sup>

### Test for Saponins:

To identify saponins, an herbal extract was swirled. 5 ml of warm aqueous extract was shaken thoroughly to produce stable foam, confirming the presence of saponins.

### Test for Alkaloids:

Iodine Test: In 3 ml of test solution in a clean test tube add a few drops of dilute iodine solution which resulted in the appearance of a blue color that can disappear after boiling and will reappear after cooling the same solution, this represents the existence of alkaloids.

Wagner's Test: In a test tube, place 2-3 ml of extract and add Wagner's reagent dropwise to it. The creation of a striking reddish-brown precipitate proved evidence of alkaloids.<sup>xiv</sup>

### Test for Steroids:

Different samples of 0.5 g of methanolic extract are mixed with 2 ml of sulfuric acid, after which 2 ml of acetic anhydride is introduced into the solution. A color transition from violet to blue or green indicates the presence of steroids in the extract obtained from *Tridax procumbens*.

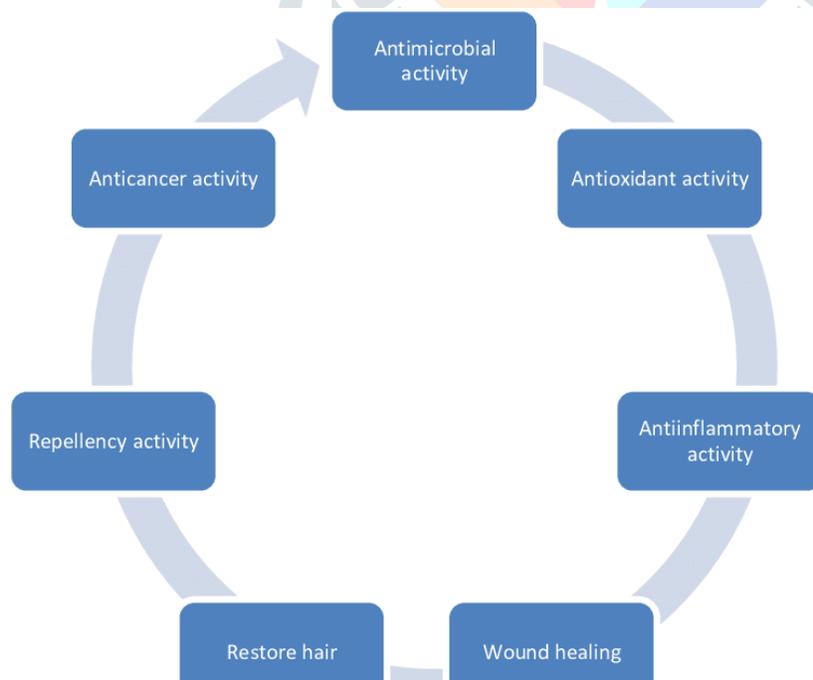


Figure 4: Summary of pharmacological activities of *Tridax procumbens*

**Pharmacological activity:-** The considerable presence of secondary metabolites in *Tridax* suggests the possible pharmacological attributes of this species. (Table 6), however, we have yet to see the use in allopathic medicine. These compounds have been implemented for their properties in anemia prevention, liver protection, immuno-enhancement, antioxidant, anticancer, antibacterial, antifungal, antiparasitic, anti-splasmoidal, and antiviral activities. This species could create a bridge between traditional and Western treatments due to its pharmacological features. More extraction, identification, and characterization of active components are needed.

There is no research confirming whether there are changes in activity during the preparation and isolation of the pharmacological compounds.

Table 5: Pharmacological Activity of *Tridax procumbens* linn. Summary

Activity	Plant Part used	Extracts/Compounds	Extracts/Solvent	Effects	Dose	References
Anti-microbial	Leaves	Pet ether; Chloroform; Ethanol	_____	<i>Bacillus subtilis</i> , <i>B. faecalis</i> , <i>E.coli</i> , <i>Pseudomonas aeruginosa</i>	200 µg/mL, 600 µg/mL 800 µg/mL	(Chen, Chemical-constituent diversity of <i>Tridax procumbens</i> , 2008) <sup>xv</sup>
	Whole plant	Ethyl acetate, n-hexane	_____	<i>E.coli</i> , <i>Salmonella group</i> , <i>S. paratyphi</i> <i>Bacillus sp.</i> , <i>Klebsiella sp.</i> , <i>S. aureus</i> , <i>Mycobacterium smegmatis</i> ,		Taddie and Rosas Romero 2000) <sup>xvi</sup>
	Fresh leaves	Hydro distillation of oil	_____	<i>S. aureus</i> , <i>S. pneumonia</i> . <i>P. aeruginosa</i> , <i>E.coli</i> <i>Candida albicans</i> , <i>Candida parapsilosis</i> and <i>Candida tropicalis</i>	MIC/MFC 25-100 µg/mL	(Manjamala i A. V., 2012) <sup>xvii</sup>
	Aerial part	3-O-methylquercetin-4'-O-β-Dglucopyranoside, Queracetangatin- 3, 6-4'-trihydroxy-7-O-β-Dglucopyranoside, Queracetangatin- 3, 6-4'-trihydroxy-7-Oneohesperidosid	Ethanol	DPPH		(Chen, Chemical-constituent diversity of <i>Tridax procumbens</i> , 2008)
Anti-oxidant activity	Whole plant	Phenolic compounds	Ethanol	DPPH Assay		(Habiba, 2010) <sup>xviii</sup>

	Leaves	Phenolic compounds	Ethanol	Reducing Power DPPH Assay		(Syed, 2020) <sup>xix</sup>
	Aerial parts		95% Ethanol	SGC-7901 and HL-60 cells	100 $\mu$ mol/L	(Chen et al., 2008) (Chen, Chemical-constituent diversity of <i>Tridax procumbens</i> , 2008)
Anti-cancer Activity	Flowers	(3S, 5R, 6S, 7E) - 5, 6 epoxy 3-hydroxy-7- megastigmene-9-one	Aqueous Acetone	Acetone - 82.28% Aqueous 6.6% cell death against PC3 (Prostate epithelial cancer cells)	250 $\mu$ g/mL	(Priya et al., 2011a) <sup>xx</sup>
	Leaves		Aqueous Acetone	Acetone – 93.00% Aqueous 6.6% cell death PC3 (Prostate epithelial cancer cells)	250 $\mu$ g/mL	(Vishnu Priya, 2011) <sup>xxi</sup>
	Whole plant			Animal		(Udupa, 1991) <sup>xxii</sup>
Wound-healing Activity	Leaf		Aqueous Extract AgNPs	Fish species <i>Pangasius hypophthalmus</i>		(Ravindran, 2019) <sup>xxiii</sup>
	Leaf		Alcoholic leaf extract formulation	Excision wound model in mice		(Deshmukh, 2018) <sup>xxiv</sup>
	Leaf juice		Topical ointment formulation		1 or 4 mg/g	(Yaduvanshi 2011) <sup>xxv</sup>

	Stem	Flavonoids, Phenols and Tannin	Aqueous	(150–200 g) (Excision wound model)	Cipladine (5 mg/ml) as positive contro	(Talekar, 2017) <sup>xxvi</sup>
	Fresh leaves		Ethanollic	Relaxation effect of <i>Corpus cavernosum</i> 150	0.15 mg/mL to 1.5 mg/mL	Salahdeen H. I., 2015) <sup>xxvii</sup>
Vasorelaxant Activity	Leaves	Sodium, Potassium, Calcium	Aqueous	Vasorelaxation effect on Male Wistar Albino rats(200–300 g)	0.5 - 9.0 mg/mL	Salahdeen H. I., 2015) <sup>xxviii</sup> (Gamboa-Leon, 2014) <sup>xxix</sup>
	Leaves	Flavonoids, aqueous alkaloids, etc.	Aqueous	L-NAME hypertensive rats	40 mg/kg/bo d	
Anti-hypertensive effect	Whole plant		Methanol	Leishmania Mexicana		
Anti-inflammatory Activity	Leaves	Terpenoids, Flavonoids	Methanol	Showed very good anti-inflammatory effect, 34% BALB/c; (20-30g)		(Manjamala i A. V., 2012) <sup>xxx</sup>

### Antimicrobial Activity:-

*Tridax procumbens* exhibits notable antimicrobial activity against a variety of bacteria, including *Escherichia coli* and *Staphylococcus aureus*. The juice of the plant can be extracted by manually compressing the entire plant between the palms. Typically, the leaf extract of *T. procumbens* is prepared using the Soxhlet extraction technique. Fresh plant juice, when applied twice daily for 3 to 4 days, has been found to promote the healing of cuts and wounds effectively.

The extract from the whole plant has demonstrated antibacterial properties, not only against bacteria but also showing sensitivity against different fungal species, indicating its broad-spectrum antimicrobial potential. The antibacterial activity of *T. procumbens* is attributed to its phytochemical constituents, including tannins and alkaloids. Tannins, known for their antibacterial potential, react with proteins to form stable, water-soluble compounds that disrupt bacterial cell membranes, leading to bacterial cell death. Alkaloids, another significant component, are believed to contribute substantially to the plant's antibacterial activity.

Specific extracts of the plant have shown varying degrees of efficacy. The *n*-hexane extract of the flowers has exhibited antibacterial activity against *E. coli*, while the extract obtained from the entire aerial parts (leaves, stems, and flowers) demonstrated effectiveness against *Mycobacterium smegmatis*, *E. coli*, *Salmonella group C*, and *Salmonella paratyphi*. The ethyl acetate extract derived from the flowers was effective against *Bacillus cereus* and *Klebsiella* species. Extracts containing aerial parts of the plant showed activity specifically against

*Mycobacterium smegmatis* and *Staphylococcus aureus*. However, the water-based extract of *T. procumbens* did not display substantial antibacterial activity.

Interestingly, none of the tested preparations showed effectiveness against yeasts (*Candida albicans*, *Candida tropicalis*, *Rhodotorula rubra*) or fungi (*Aspergillus flavus*, *Aspergillus niger*, *Mucor* species, and *Trichophyton rubrum*). These findings highlight the selective antimicrobial properties of *T. procumbens* and its potential as a source of bioactive compounds for targeted antibacterial applications.

**Table 6: Antimicrobial activity of *Tridax procumbens***

Sr.No.	Type of extract	Active against
1.	Extract of flowers	<i>E.coli</i>
2.	Whole plant extract	<i>Mycobacterium smegmatis</i> , <i>E. coli</i> , <i>Salmonella</i> group C and <i>Salmonella paratyphi</i> .
3.	Ethyl acetate extract	<i>Bacillus cereus</i> and <i>Klebsiella sp.</i>
4.	Arial part extract	<i>Mycobacterium smegmatis</i> and <i>Staphylococcus aureus</i>
5.	Aqueous extract	No antimicrobial activity



## Free Radical Scavenging and Antioxidant Activity:

Free radicals produced at or near wound sites significantly delay wound healing by damaging lipids, proteins, collagen, proteoglycans, and hyaluronic acid. *Tridax procumbens* exhibits potent antioxidant properties that facilitate wound healing by preserving viable tissues and preventing oxidative damage. Free radicals, characterized by their instability, interact with macromolecules, including DNA, causing cellular damage and homeostatic imbalance. Antioxidants act as radical scavengers, reducing oxidative activity and preventing cellular damage. The antioxidant activity of *T. procumbens* is attributed to its phenolic compounds, flavonoids, anthraquinones, and vitamins A and C. Notably, extracts derived using *n*-butanol and ethyl acetate from ethanol extracts have demonstrated high antioxidant efficacy. The plant also minimizes lipid peroxidation while enhancing both enzymatic and non-enzymatic antioxidant systems.

## Anticancer Activity:

Cancer is a heterogeneous group of diseases involving the uncontrolled proliferation of abnormal cells, often leading to metastasis—a major cause of cancer-related mortality. Studies on prostate epithelial malignant cells (PC3) revealed that while the aqueous extract of *T. procumbens* flowers showed limited antitumor activity, the acetone extract exhibited significant cytotoxic activity, with an 82.28% reduction in cancer cell viability within 24 hours. Additionally, *T. procumbens* inhibited tumour nodule development in lung tissue, likely due to its monoterpene content that suppresses angiogenesis. Essential oils extracted from the plant's leaves and flowers demonstrated concentration-dependent anticancer effects on the MCF-7 breast cancer cell line, further highlighting its potential in oncology.<sup>xxi</sup>

## Wound Healing Activity:

The wound healing potential of *Tridax procumbens* is attributed to its phytochemicals, including flavonoids, tannins, polyphenols, and terpenoids, which facilitate tissue repair. Aqueous leaf extracts and silver nanoparticles synthesized from the plant have shown enhanced wound healing activity in experimental models, including fish and steroid-depressed wound healing in rats. Increased lysyl oxidase activity, hydroxyproline turnover, and collagen synthesis were observed during the healing process. These findings underscore the plant's ability to accelerate both the initial and later stages of wound healing, with potential applications in managing chronic wounds.

## Anti-inflammatory Activity:

The anti-inflammatory properties of *T. procumbens* were evaluated in a carrageenan-induced mouse paw oedema model. Ethanolic leaf extracts significantly reduced inflammation and restored normal histology within 24 hours. Molecular studies demonstrated a reduction in cyclooxygenase-2 (COX-2) and tumour necrosis factor (TNF- $\alpha$ ) expression at the site of inflammation, indicating activity at the gene expression level. These findings support the plant's potential as an anti-inflammatory agent for conditions involving acute and chronic inflammation.

## Hepatoprotective Activity:

*Tridax procumbens* exhibits hepatoprotective effects by mitigating oxidative stress in liver tissues. Experimental studies on male albino rats with induced liver damage showed that ethanolic and water-based extracts reduced serum biomarkers, including aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), and bilirubin. Regeneration of parenchymal liver cells was observed, attributed to the antioxidant properties of the plant. Additionally, chloroform-fractionated ethanolic extracts demonstrated significant hepatoprotective activity against d-Galactosamine lipopolysaccharide-induced hepatitis, suggesting its potential for liver-related disorders.

## Hair Growth Promotion:

The ethanolic extract of the aerial parts of *T. procumbens* demonstrated hair growth-promoting effects in albino rats. Topical application as a 10% ointment and oral administration (100 mg/kg/day) over 20 days showed significant improvement in hair growth. The petrol fraction obtained through column chromatography exhibited potent activity, indicating the therapeutic potential of specific plant constituents for alopecia management.

## Antimalarial Activity:

Essential oils extracted from *T. procumbens* foliage via steam distillation showed significant repellent activity against *Anopheles stephensi*, the vector of malaria. At a 6% oil concentration, a strong repelling effect was observed for over 300 minutes, highlighting the plant's potential as a natural antimalarial agent.

## Analgesic Activity:

Lyophilized decoctions of *T. procumbens* leaves exhibited notable analgesic effects in rats. Tests using acetic acid-induced writhing, formalin-induced pain, and Complete Freund's Adjuvant (CFA)-induced hyperalgesia demonstrated a dose-dependent reduction in pain perception. These findings suggest the plant's potential in managing both acute and chronic pain conditions.

## Vasorelaxant and Antihypertensive Activity:

Studies on rat aortic rings revealed that *T. procumbens* leaf extracts induce vasorelaxation through calcium antagonism. Water-based extracts reduced contraction induced by norepinephrine and calcium chloride. The vasodilatory effect was significantly diminished in the presence of cyclic GMP and AMP inhibitors, indicating the involvement of these pathways. These results suggest potential applications in the management of hypertension and vascular disorders.

## Antidiabetic Activity:

The hypoglycaemic activity of *T. procumbens* was evaluated in alloxan-induced diabetic rats. Alcoholic and aqueous extracts at a dose of 200 mg/kg significantly reduced blood glucose levels, while petroleum ether extracts showed minimal activity. These findings suggest the potential utility of the plant in managing diabetes and related metabolic disorders.

## Anti-Ulcer Activity:

Ethanolic extracts of *T. procumbens* leaves demonstrated anti-ulcer activity in rats with ethanol-induced gastric lesions. A dose of 400 mg/kg reduced the ulcer lesion index, modulated stomach pH, and improved fibroblast regeneration. The extract also restored glutathione (GSH), catalase, and superoxide dismutase (SOD) levels, highlighting its gastroprotective properties.<sup>xxxi</sup>

## Anti-Parkinson's Activity:

Ethanollic extracts of *T. procumbens* leaves exhibited neuroprotective effects in Parkinson's disease models. In rotenone-induced fruit fly models and haloperidol-induced cataleptic rats, the extract significantly improved locomotor performance, reduced muscle rigidity, and minimized lipid peroxidation. These effects were accompanied by increased antioxidant enzyme levels, suggesting potential applications in neurodegenerative disorders.<sup>xxxii</sup>

## Conclusion

*Tridax procumbens*, a widely distributed weed with significant medicinal potential, holds a prominent place in traditional Ayurvedic medicine due to its extensive pharmacological profile. Its bioactive constituents, such as alkaloids, flavonoids, tannins, glycosides, sterols, saponins, polyphenols, and vitamins, contribute to its multifaceted therapeutic applications. This review highlights its broad spectrum of activities, including antimicrobial, antioxidant, anti-inflammatory, wound healing, hepatoprotective, antidiabetic, anti-ulcer, anticancer, and neuroprotective effects, as well as its potential in promoting hair growth and acting as an antimalarial and analgesic agent.

## Key Insights for Future Research:

- 1. Phytochemical Exploration:** While the phytochemical profile of *T. procumbens* has been partially elucidated, advanced analytical techniques like LC-MS/MS, GC-MS, and NMR spectroscopy could identify novel bioactive compounds. This would deepen our understanding of its therapeutic mechanisms and open avenues for drug discovery.
- 2. Mechanistic Insights:** Many of the pharmacological activities, such as antioxidant, anticancer, and anti-inflammatory effects, have been demonstrated. However, detailed molecular mechanisms and pathway-level interactions need to be elucidated to bridge the gap between traditional use and modern pharmacology. Studies focusing on key pathways, such as NF- $\kappa$ B, MAPK, and PI3K-Akt, could provide valuable insights.
- 3. Clinical Relevance:** Most studies on *T. procumbens* have been conducted in vitro or in animal models. Rigorous clinical trials are essential to validate its efficacy, safety, and therapeutic window in humans. These trials should also explore pharmacokinetics, bioavailability, and potential drug-herb interactions.
- 4. Formulation Development:** The incorporation of *T. procumbens* into novel drug delivery systems, such as nanoparticles, liposomes, and hydrogels, could enhance its bioavailability and therapeutic efficacy. Its use in topical formulations for wound healing and hair growth warrants further investigation, especially in commercial pharmaceutical applications.
- 5. Standardization and Quality Control:** Establishing standardized extraction protocols and quality control measures is critical for consistent therapeutic outcomes. Marker compounds should be identified and quantified to ensure batch-to-batch uniformity in herbal formulations derived from *T. procumbens*.
- 6. Multifunctional Applications:** *T. procumbens* demonstrates a unique combination of pharmacological properties, making it a candidate for multifunctional therapeutic strategies. For instance, its antioxidant and anti-inflammatory properties could be harnessed for managing chronic diseases such as diabetes, neurodegenerative disorders, and cancer, which involve oxidative stress and inflammation.
- 7. Sustainable Utilization:** Given its widespread availability and potential applications, sustainable cultivation and harvesting practices should be promoted. This would ensure the availability of raw materials without depleting natural ecosystems.
- 8. Integration into Modern Medicine:** By leveraging modern biotechnological approaches, such as genetic engineering and tissue culture, *T. procumbens* can be further explored to optimize the yield of its bioactive

constituents. Integration with synthetic biology could enable large-scale production of specific compounds for pharmaceutical use.

The comprehensive pharmacological review of *Tridax procumbens* establishes it as a promising candidate for further exploration in the pharmaceutical sciences. This review not only consolidates existing knowledge but also identifies gaps that can guide future research efforts. With its strong ethnopharmacological foundation, rich phytochemical profile, and demonstrated therapeutic potential, *T. procumbens* has the potential to contribute significantly to drug discovery and development.

Publishing this review in a high-impact journal would not only advance the scientific understanding of *T. procumbens* but also provide a roadmap for translating its traditional uses into evidence-based medicine. This could catalyse interdisciplinary collaborations among pharmacologists, biochemists, clinicians, and formulation scientists, fostering innovation in natural product research and drug development.

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