

Review Article

Tridax procumbens: A Comprehensive Review on its Phytochemistry, Pharmacological activities and Therapeutic Potential

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ABSTRACT

Tridax procumbens Linn. (Compositae) is a widely distributed medicinal plant known for its diverse pharmacological properties. Traditionally used in Ayurveda and folk medicine, this plant has demonstrated hepatoprotective, immunomodulatory, wound healing, antidiabetic, hypotensive, antimicrobial, anti-inflammatory, antioxidant, and insect-repellent activities. Additionally, it exhibits antidiarrheal, Antileishmanial, anticancer, anti-arthritic, anti-Lithiatic, and hair growth-promoting effects, making it a promising candidate for natural therapeutic development. The plant is also explored for its potential in phytoremediation, particularly in the removal of toxic heavy metals like Cr (VI) from industrial wastewater. Phytochemical investigations reveal the presence of flavonoids, alkaloids, tannins, saponins, sterols, and triterpenoids, with oleanolic acid being one of the key bioactive constituents. Despite its traditional medicinal use, further research is required to elucidate the mechanisms of action, isolate active compounds, and establish pharmacokinetic-pharmacodynamics (PK-PD) correlations. Employing bioassay-guided phytochemical identification, molecular modelling, and phenotypic screening can aid in developing standardized herbal formulations and novel therapeutic agents. This review highlights the multifaceted therapeutic potential of *T. procumbens* and emphasizes the need for advanced pharmacological and clinical studies to validate its efficacy and safety for modern medicinal applications

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Introduction:

Nature has long been a source of inspiration for humanity, transcending cultural and religious boundaries. Herbal medicine, rooted in traditional knowledge, continues to play a crucial role in the treatment of various ailments across both developed and developing nations. *Tridax procumbens* Linn.,

commonly known as "Coat Buttons," is a medicinal plant originally native to Central America but now widely distributed across tropical and subtropical regions. This plant holds significant value due to its diverse pharmacological activities and its mention in several Ayurvedic formulations.

Morphology:

Tridax procumbens is a perennial herb with a creeping stem that can grow between 20 to 75 cm in length.

Leaves: The leaves are arranged oppositely, with an ovate to oblong shape, measuring around 2.5-5 cm in length. They have serrated margins, a wedge-shaped base, and an acute apex, with both surfaces covered in fine hairs.

Flowers: The plant produces small daisy-like flowers with white ray florets and yellow disc florets. The inflorescence is capitulum-type, with flowers that can sometimes have three lobes. The plant exhibits basal placentation and blooms throughout the year.

Fruits: The fruits are dark brown to black achenes, oblong in shape, and about 2 mm long. Each fruit bears a feathery pappus, aiding in wind dispersal and contributing to the plant's invasive nature.

Seeds: Germination occurs at higher temperatures (30-35°C) under moderate light conditions. The plant is sensitive to saline conditions and water stress. It primarily reproduces through seed dispersal and vegetative propagation via its spreading stems.

Stem and Root: The stem is cylindrical, branched, and sparsely covered with hair, while the plant has a strong taproot system. [Debolina et al 2022 and Chaudhari et al 2018].

Fig. 1: *Tridax procumbens* and flower



Tridax Procumbens plant



Tridax Procumbens flowers

Fig. 2: *Tridax procumbens* flower morphology



CLASSIFICATION FOR KINGDOM PLANTAE DOWN TO SPICES TRIDAX PROCUMBES L. [Chaudhari et al 2022]

Sr.No.	Rank	Scientific Name
1	Kingdom	Plantae: plants
2	Subkingdom	Teacheobionta: vascular plant
3	Superdivison	Spermatophyta: Seed plant
4	Divison	Magnoliophyta: Flowering plant
5	Class	Magnoliopsida: Dicotyledons
6	Subclass	Asteridae
7	Order	Asterales
8	Family	Asteraceae
9	Genus	Tridax L.
10	Species	Tridax Procumbens L

CLASSIFICATION OF TRIDAX PROCUMBENS LINN: [Pawar et al 2017]

English	Coat button and Tridax daisy
Marathi	Dagadi pala
Sanskrit	Jayanti veda
Malayam	Chiravanak
Telgu	Gaddi chamanti
Tamil	That pudu
Chinese	Kotubuki Goku
Spanish	Cadillo chisaca
French	Herb caille

PHYTOCONSTITUENTS:

Several studies have confirmed the presence of various bioactive compounds in *Tridax procumbens*.

Phytochemical screening has identified alkaloids, carotenoids, flavonoids, tannins, and Saponins in different parts of the plant. Mineral analysis indicates that the plant is rich in sodium, potassium, and calcium.

The leaves contain approximately 26% crude proteins, 17% crude fiber, 39% soluble carbohydrates, and 5% calcium oxide. Additionally, compounds such as luteolin, glucoluteolin, quercetin, and isoquercetin have been isolated from the flowers. Other notable phytochemicals include fumaric acid, β -sitosterol, and oleanolic acid, the latter of which has demonstrated potential as an anti-diabetic agent through inhibition of alpha-glucosidase.

The plant also contains a diverse range of secondary metabolites, including:

Flavonoids: Echioidinin, pinostrobin, dihydroechioidinin, skullcap flavone I & II, tectochrysin, and androechin.

Phenolic compounds: 2,6-dihydroxyacetophenone, 2-O- β -D-glucopyranoside, methyl salicylate glucoside, and 5,7,8-trimethoxyflavone.

Terpenoids and steroids: Taraxasteryl acetate, β -amyrinone, lupeol, and betulinic acid.

Triterpenoids: Oleanolic acid and its derivatives.

Recent research has also led to the isolation of a novel flavonoid, procumbenetin, from the aerial parts of the plant, along with two newly identified flavones:

8,3'-dihydroxy-3,7,4'-trimethoxy-6-O-D-glucopyranosyl

6,8,3'-trihydroxy-3,7,4'-trimethoxy

Additionally, water-soluble polysaccharides (WSTP-IA and WSTP-IB) have been purified from *Tridax procumbens* leaves through ethanol precipitation and chromatographic techniques.

The plant's pigment composition has also been studied, revealing a total chlorophyll content of 1.424 mg/g tissue and total carotenoid content of 0.724 mg/g tissue. However, these values may vary due to environmental conditions such as air pollution and seasonal changes.

The presence of hydroxycinnamates, lignans, benzoic acid derivatives, and phytosterols further contributes to the plant's medicinal potential, making *Tridax procumbens* a valuable resource for pharmacological and nutraceutical applications.

Other Phytochemicals

Several other bioactive compounds have been identified in the leaves of *Tridax procumbens*, including caffeic acid, ferulic acid, tannins, Stigmasterol, and lutein. These compounds contribute to the plant's diverse pharmacological properties.

Caffeic Acid & Ferulic Acid: These phenolic acids exhibit antioxidant, anti-inflammatory, anticancer, and antimicrobial activities, making them valuable in disease prevention and treatment.

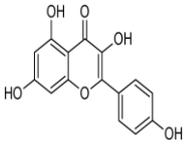
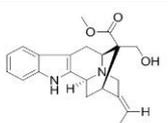
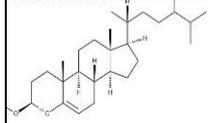
Tannins (Tannic Acid & Hydrolysable Tannins): Known for their multiple health benefits, tannins have been associated with a reduced risk of cardiovascular diseases, anticancer properties, antidiarrheal effects, anti-obesity potential, and antimicrobial activities. They also exhibit antiviral, antifibrotic, and neuroprotective properties, partly through their ability to inhibit Ca²⁺-activated Cl⁻ channels.

Stigmasterol: This plant sterol is recognized for its anti-osteoarthritic, antihypercholesterolemic, antitumor, hypoglycaemic, antimutagenic, antioxidant, anti-inflammatory, and analgesic effects.

Lutein: A xanthophyll carotenoid, lutein plays a crucial role in eye health, protecting against

conditions such as age-related macular degeneration (AMD), age-related cataracts (ARC), ischemic/hypoxia-induced retinopathy, retinal light damage, retinitis pigments, retinal detachment, uveitis, and diabetic retinopathy. Additionally, lutein has been linked to reduced risks of lung and breast cancers, cardiovascular diseases, and stroke.

Table 1: Important Plant constituents of *Tridax procumbens*

Sr. No.	Name of main Phytoconstituents	Total No		Test for identification	Structure
1	Flavonoid	23	Kaempferol and catechin and its derivatives (-)-epicatechin, (+)-catechin, (-)-epigallocatechin, (+)-gallocatechin, (-)-Epigallocatechin-3-Gallate (EGCG) and (-)-Epicatechin-3-Gallate) account for about 17.59% and 26.3% respectively. The remaining 56.11% represent sixteen flavonoids namely biochanin, apigenin, naringenin, daidzein, quercetin etc	Shinoda Test (Mg/HCl):	
2.	Alkaloids	39	Akuamidine (73.91%) and Voacangine (22.33%)	1. Ayer's test 2. Ager's test 3. Wagner's test 4. Dragendorff's test	
3	Saponins		pB-Sitosterol-3-O-β-D-xylopyranoside	Foam test	

PHARMACOLOGICAL ACTIVITY:

[Amutha et al 2009]

1. Wound healing
2. Hepatoprotective
3. Immunomodulatory
4. Antidiabetic activity
5. Antimicrobial activity
6. Anti-cancerous activity
7. Antimalarial
8. Antifungal
9. Antibacterial
10. Antioxidant activity
11. Antiarthritic
12. Anti-juvenile hormone activity
13. Antidiarrheal/Antisecretory activity
14. Hair growth promoting activity
15. Insecticidal activity
16. Antileishmanial activity
17. Anti-Lithiatic activity
18. Repellency activity
19. Miscellaneous

PHARMACOLOGICAL ACTIVITY:

1. Wound-Healing Activity

Wound healing is a complex biological process that involves the restoration of cellular structures and tissue layers. *Tridax procumbens* has demonstrated significant wound-healing potential in various studies, particularly through its water and ethanol extracts.

Research indicates that the aqueous extract of the whole plant facilitates both normal and immune-compromised wound healing in animal models. It counteracts the anti-epithelization and tensile strength-depressing effects of dexamethasone, a well-known wound-healing suppressant, without interfering with its anti-contraction and anti-granulation effects. The wound-healing mechanism of *Tridax procumbens* involves a complex interaction between dermal and epidermal cells, extracellular matrix components, plasma-derived proteins, controlled angiogenesis, and cytokine-regulated growth factors.

The plant extract enhances wound healing by:

- Increasing lysyl oxidase activity, which strengthens collagen fibres.

- Boosting protein and nucleic acid synthesis in granulation tissue.
- Elevating glycosaminoglycan levels, which play a crucial role in tissue repair.

Experimental Evidence

In a study using animal models, both excision and incision wounds were treated with *Tridax procumbens* extracts:

- Incision wounds: Treated for 14 days, after which wound-healing capacity was assessed using a tensiometer. Skin samples were analysed histopathologically to evaluate re-epithelization and collagen formation.
- Excision wounds: Treated for 15 days, with wound area reduction monitored every three days using graph paper analysis.

Biochemical assessments showed a significant increase in hydroxyproline, collagen, and hexosamine content, all of which indicate enhanced tissue regeneration and effective wound healing. [Chaudhari et al 2022]

2. Hepatoprotective Activity

The aerial parts of *Tridax procumbens* exhibit significant hepatoprotective effects, particularly in D-Galactosamine/Lipopolysaccharide (D-GalN/LPS)-induced hepatocellular injury. D-GalN and LPS are known to cause liver toxicity by inducing hepatocyte destruction, leading to multifocal necrosis. The hepatic damage caused by D-GalN is comparable to viral hepatitis in humans, as it selectively inhibits transcription and indirectly blocks hepatic protein synthesis. Due to endotoxin toxicity, it can cause fulminant hepatitis within eight hours of administration. The hepatoprotective action of *Tridax procumbens* is attributed to its potential to counteract these effects, thereby protecting liver cells. [Vilwanathan et al 2005]

3. Immunomodulatory Activity

Ethanollic extracts of *Tridax procumbens* leaves have been found to possess immunomodulatory effects, particularly in albino rats infected with *Pseudomonas aeruginosa*. Studies have shown that the extract:

- Inhibits bacterial proliferation.
- Increases phagocytic index, leukocyte count, and splenic antibody-secreting cells when tested using the ethanol-insoluble fraction of the aqueous extract.
- Enhances humoral immune response by increasing hem agglutination antibody titres.

These findings suggest that *Tridax procumbens* may serve as a natural immune booster, supporting both innate and adaptive immunity. [Oladunmove et al 2008]

4. Antidiabetic Activity

The aqueous and alcoholic extracts of *Tridax procumbens* leaves have demonstrated significant blood glucose-lowering effects in animal models of alloxan-induced diabetes. The plant extract aids in:

Reducing hyperglycaemia, suggesting its potential as a natural antidiabetic agent.

Regulating insulin-dependent glucose metabolism, which could help in managing diabetes mellitus.

These effects highlight *Tridax procumbens* as a promising herbal remedy for diabetes management. [Bhagwat et al 2008]

5. Antimicrobial Activity

The whole plant of *Tridax procumbens* has been traditionally used for antimicrobial purposes, particularly for treating wounds and cuts. The fresh plant juice, obtained by squeezing between the palms, is applied topically twice daily for 3–4 days to promote healing.

In antibacterial studies, the whole-plant extract exhibited activity specifically against *Pseudomonas aeruginosa*.

The disk diffusion method was employed to evaluate the antibacterial properties against four bacterial strains:

- Gram-positive bacteria: *Bacillus subtilis*, *Staphylococcus aureus*
- Gram-negative bacteria: *Escherichia coli*, *Pseudomonas aeruginosa*. [Mahato et al 2005]

6. Anticancer Activity

Tridax procumbens contains phytochemicals with anticancer properties, particularly against human lung cancer cells. Cytotoxicity studies using the MTT assay on dried leaf extracts revealed that a compound with an Rf value of 0.66 reduced cancer cell viability by 90%. Structural characterization using NMR, MS, and IR spectroscopy identified this compound as Lupeol.

Further anticancer evaluations demonstrated that Lupeol: Suppresses colony formation in cancer cells.

Regulates the cell cycle, leading to controlled cell growth.

Inhibits COX-2 activity, a key enzyme in inflammation and cancer progression.

Induces DNA fragmentation, promoting apoptosis (programmed cell death).

At a concentration of 320 µg/ml, Lupeol exhibited significant anticancer potential, highlighting *Tridax procumbens* as a promising natural candidate for lung cancer therapy. [Jindal et al 2013]

7. Antimalarial Activity

The aqueous and ethanolic extracts of *Tridax procumbens* have demonstrated antiplasmodial activity against chloroquine-resistant *Plasmodium falciparum*, the causative agent of malaria.

Key findings include:

The extracts effectively inhibited parasite growth.

Low toxicity to human red blood cells, suggesting a safe profile.

These results support the traditional use of *Tridax procumbens* in treating malaria. However, comprehensive animal toxicity studies are necessary to establish its safety and efficacy for human applications. [Pie et al 2011].

8. Antifungal Activity

The antifungal potential of *Tridax procumbens* was assessed using the disc diffusion assay against pathogenic fungal strains: *Aspergillus flavus* and *Aspergillus Niger*.

Minimum Inhibitory Concentration (MIC) and Minimum Fungicidal Concentration (MFC) were determined to assess the plant's effectiveness.

Flavonoid-rich extracts exhibited strong antifungal activity, particularly against *A. Niger*.

Alkaloid extracts showed no antifungal effects.

Remarkable antifungal activity was observed in free flavonoids from the stem and bound flavonoids from the stem and flowers. These findings indicate that *Tridax procumbens* could be a natural source for antifungal drug formulations, particularly for treating infections caused by *A. Niger*. [Chaudhari et al 2018]

9. Antibacterial Activity

Tridax procumbens, a common herb in tropical regions, exhibits antibacterial properties, particularly against *Pseudomonas aeruginosa*.

Ethanolic extracts of the plant demonstrated significant antibacterial activity.

This effect was observed only against *P. aeruginosa* strains.

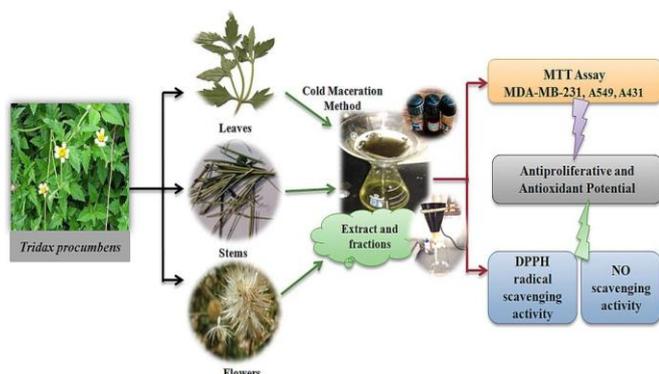
Multi-drug-resistant (MDR) *Pseudomonas* strains, isolated from ventilator-associated pneumonia, urinary tract infections, and bloodstream infections, showed notable sensitivity to *Tridax* extracts.

These findings suggest that *Tridax procumbens* could serve as a natural anti-pseudomonal agent, potentially contributing to the development of herbal formulations for treating nosocomial infections caused by *Pseudomonas aeruginosa*. [Agrawal et al 2009]

10. Antioxidant Activity

Antioxidants are molecules that inhibit oxidation, preventing cellular damage caused by free radicals. The antioxidant activity of *Tridax procumbens* extracts was evaluated using the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging assay.

Figure 3: *Tridax procumbens* extract antioxidant activity



Key observations:

- Ethyl acetate and n-butanol fractions from the ethanolic extract exhibited significant antioxidant activity.
- The antioxidant potential of these fractions was comparable to ascorbic acid (Vitamin C), a known standard antioxidant.
- Fractionation of the plant extract helped isolate bioactive phytochemicals, offering a clearer understanding of the specific compounds responsible for its antioxidant effects.

11. Anti-Arthritic Activity

Arthritis is an inflammatory disorder that leads to the degeneration of joints, often exacerbated by inadequate hydration and modern lifestyle habits. Several studies have examined the anti-arthritic potential of *Tridax procumbens*.

- Ethanolic extracts of the plant, tested at doses of 250 mg/kg and 500 mg/kg, exhibited significant anti-arthritic activity.
- Indomethacin (10 mg/kg) was used as a standard reference drug for comparison.
- The Freund's Complete Adjuvant (FCA) model was used to assess the plant's efficacy.
- The results indicated that *Tridax procumbens* extract had a comparable effect to Indomethacin, suggesting its potential as a natural remedy for arthritis management.

12. Anti-Juvenile Hormone Activity

Juvenile hormones (JH) play a crucial role in insect growth, development, and metamorphosis. Certain plant extracts have been identified as juvenile hormone analogs or antagonists, influencing insect life cycles.

- A petroleum ether extract fraction of *Tridax procumbens* exhibited significant effects on metamorphosis in *Dysdercus* species.
- The extract disrupted normal adult development, leading to abnormal morphological changes.
- Among 15 tested plant species, *T. procumbens*, along with *Eichhornia crassipes*, *Ageratum conyzoides*, *Cleome icosandra*, and *Targets erects*, showed notable juvenile hormone-like effects against late fourth instar larvae and adult female mosquitoes.

- **Observed effects included:**

- Growth inhibition
- Larval-pupal intermediates
- Malformed pupae
- Defective egg rafts
- Adults with deformed flight muscles
- The extract also altered biting behaviour in mosquitoes (*Culex quinquefasciatus*), though no sterilizing effects were observed.
- The fecundity (egg-laying capacity) of treated mosquitoes was significantly reduced, and egg rafts produced by exposed adults were shorter than in control groups.

13. Antidiarrheal/Antisecretory Activity

The antisecretory potential of *Tridax procumbens* was evaluated alongside 31 indigenous medicinal plants from India. Various extracts, including alcoholic, hexane, chloroform, butanol, and aqueous extracts, were screened for their activity against *Escherichia coli*-induced secretory diarrhoea. The extract of *T. procumbens* exhibited a highly significant antisecretory effect, indicating its potential use in treating diarrheal disorders caused by bacterial infections.

14. Hair Growth-Promoting Activity

The ethanolic extract of *T. procumbens* aerial parts was investigated for its ability to promote hair growth in albino rats. The study involved two administration routes:

- Topical application of a 10% ointment
- Oral administration at 100 mg/kg/day for 20 days

Findings revealed that:

- Both treatment groups showed significant hair growth, while the control group remained largely hairless.

- Petroleum ether fractions were identified as the most active components.
- Column chromatography of the petroleum ether fraction further confirmed the bioactivity.
- Hair growth initiation was not observed until the 10th day; however, by the 14th day, the process had started, and by 21 days, hair growth was almost complete.

This study suggests that *T. procumbens* could be a potential natural remedy for hair loss treatment.

15. Insecticidal Activity

The essential oils extracted from *Tridax procumbens* exhibited potent insecticidal properties against multiple insect species, including:

- House flies
- Mosquito larvae
- *Dysdercus similes*
- Cockroaches

Additionally, *T. procumbens* essential oils demonstrated strong insect repellent activity when tested against three ant species. Notably, during plant collection, it was observed that *T. procumbens* remained untouched by grazing cattle, suggesting its natural insect-repelling or insecticidal properties.

16. Antileishmanial Activity

The effectiveness of *Tridax procumbens* against *Leishmania Mexicana*, the causative agent of cutaneous leishmaniasis, was examined in combination with *Allium sativum* (garlic) extract.

- In vivo assays were conducted on mice injected with *L. Mexicana* promastigotes.
- The mice were treated with either *T. procumbens* extract alone or in combination with *A. sativum* extract for 14 days.

- After 12 weeks of infection, blood samples were analysed using non-commercial indirect ELISA to detect total immunoglobulins.
- The results demonstrated:
 - A shift towards a Type 1 immune response, indicating enhanced immune activation against *Leishmania*.
 - An increased IgG2a/IgG1 ratio, suggesting a potential therapeutic effect.

17. Anti-Lithiatic Activity

The ethanolic extract of *Tridax procumbens* has been evaluated for its potential in treating kidney stone disorders. The extract demonstrated activity against ethylene glycol (0.75% v/v) and ammonium chloride (2% w/v)-induced calcium oxalate urolithiasis in animal models.

Findings suggest that *T. procumbens*:

- Significantly reduced urinary excretion and renal deposition of calcium oxalate, thereby preventing stone formation.
- Lowered lipid peroxidation associated with hyperoxaluria-induced oxidative stress, suggesting both anti-urolithiasis and antioxidant effects.

This indicates its potential use as a natural remedy for kidney stone prevention and management.

18. Repellency Activity

Essential oils extracted from *T. procumbens* leaves through steam distillation were tested for their mosquito-repellent effects against *Anopheles stephensi*, the malaria vector.

- The oils were tested at 2%, 4%, and 6% concentrations in mosquito cages.
- The 6% concentration exhibited the highest repellency effect, providing >300 minutes of protection against *Anopheles stephensi*.

These results suggest that *T. procumbens* essential oil could serve as a natural and effective mosquito repellent.

19. Miscellaneous Activities

Cardiovascular Effects

The aqueous extract of *T. procumbens* leaves was tested on anaesthetized Sprague-Dawley rats to evaluate its cardiovascular impact. The extract caused:

- A dose-dependent reduction in mean arterial blood pressure (MABP).
- A significant reduction in heart rate at higher doses, while lower doses had no effect on heart rate.

This suggests that *T. procumbens* has a hypotensive effect, which could be explored for managing hypertension.

Anti-Inflammatory & Antioxidant Effects

- The plant exhibited anti-inflammatory and antioxidant properties, as confirmed by DPPH (2,2-diphenyl-1-picrylhydrazyl hydrate) assay and HET-CAM (Hen's Egg Chorioallantoic Membrane) assay.

Hair Growth Promotion

- *T. procumbens* leaves have been traditionally used to prevent hair fall and promote hair growth, but further scientific validation is needed.

Phytoremediation & Chromium (VI) Removal

- *T. procumbens* has been utilized in phytoremediation for removal of hexavalent chromium (Cr VI) from industrial wastewater.
- A 97% removal efficiency was achieved using 5g of *T. procumbens* bio-adsorbent in synthetic wastewater samples.

- This highlights its potential in environmental detoxification and industrial wastewater treatment.

Traditional Medicinal Uses

- *T. procumbens* leaves have been traditionally used in West Africa and tropical regions for treating:
 - Bronchial catarrh (excess mucus production in airways)
 - Dysentery and diarrhoea
 - Conjunctivitis

CONCLUSION:

Tridax procumbens Linn. (Compositae) is a widely distributed weed found throughout India, originally native to tropical America and later naturalized in tropical Africa, Asia, and Australia. Despite its classification as a weed, each part of this plant exhibits remarkable pharmacological properties. Research has demonstrated its hepatoprotective, immunomodulatory, antidiabetic, hypotensive, antimicrobial, insect-repellent, anti-inflammatory, and antioxidant activities, along with its potential in bronchial catarrh, dysentery, diarrhoea, and hair growth promotion. Additionally, *T. procumbens* has gained attention for its bio adsorbent properties, particularly in the removal of hexavalent chromium (Cr VI) from industrial wastewater. In Ayurveda, it is sometimes dispensed as "Bhringraj" due to its reputed benefits for hair and scalp health. Despite its widespread use in traditional medicine, further scientific research is essential to elucidate its mechanisms of action, identify active phytochemicals, and validate its therapeutic potential. Studies have reported the isolation of oleanolic acid, a triterpenoid, from this plant,

highlighting its potential as a source of novel bioactive compounds. However, many existing studies rely primarily on crude extracts rather than isolating and characterizing specific bioactive compounds.

Future research should focus on:

- Bioassay-guided phytochemical identification to pinpoint the compounds responsible for specific pharmacological effects.
- Phenotypic screening using relevant cell culture models to validate therapeutic claims.
- Pharmacokinetic-Pharmacodynamic (PK-PD) correlation studies to establish efficacy and safety profiles.
- Isolation of active metabolites to ensure standardized extract preparations for medicinal use.
- Screening of enzyme targets for various diseases to identify potential inhibitors or activators.
- Molecular modeling, medicinal chemistry, and bioinformatics approaches for drug discovery and development.

Given its diverse pharmacological properties and phytochemical richness, *T. procumbens* holds immense potential for the pharmaceutical industry. Systematic research and application of modern technologies can pave the way for new herbal drugs, reinforcing its role as a promising natural therapeutic agent.

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