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Phytochemical Profiling and Pharmacological Activities of *Abutilon ramosum* in Chronic Disease Management: A Comprehensive Review

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Abstract

Background: Chronic diseases like diabetes, inflammation, arthritis, and gastrointestinal disorders are globally significant health issues that generate growing interest towards alternative multi-targeted therapeutic options such as phytotherapeutic approaches. **Aim:** This review focuses on the botany, phytochemistry, and pharmacological potential of *Abutilon ramosum* with a comprehensive comparative discussion with *A. indicum*. **Methods:** The present work is an illustrative review based on literature concerning the phytochemical composition and pharmacological activities of *A. ramosum*, along with its ethanomedicinal significance and comparison with closely related species. **Results:** *Abutilon ramosum* (*Malvaceae*) is an ethnomedicinal shrub indigenous to Africa and Asia, that harbours bioactive compounds including quercetin, luteolin, gallic and ferulic acids as well as glycosides, and polysaccharides. Their constituents support their traditional use for inflammatory and metabolic disorders. Preclinical studies show its anti-inflammatory, antioxidant, anti-diabetic, anti-arthritic, and gastroprotective activities through modulation of cytokines, oxidative stress, and metabolic pathways. **Conclusion:** Although *A. ramosum* shows promising multi-target therapeutic potential compared to synthetic drugs, there is a lack of species-specific clinical studies. Future research should focus on bioassay-guided isolation, network pharmacology approaches, advanced *in vivo* studies, and clinical trials for the development of standardised extracts in the management of chronic diseases.

Major Findings: *Abutilon ramosum* exhibits significant multi-target pharmacological activities due to its rich phytochemical profile. It shows potential in managing chronic diseases such as inflammation, diabetes, and arthritis. However, clinical validation is still required.

Keywords: *Abutilon ramosum*, Anti-inflammatory, Anti-oxidant, Anti-diabetic, Anti-arthritic, Chronic Disease, Gastroprotective

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1 Introduction

Long-term illness and chronic disease, including diabetes, inflammation-related diseases and cancer, are some of the most common and debilitating health problems[1], globally and have an impact on morbidity and mortality in various populations[2]. The chronic nature of both diseases, the overlapping underlying mechanisms, and the increasing prevalence worldwide[3] have emphasised the importance of developing new strategies for management and prevention, often leading to the investigation of natural active principles and traditional medicine to find potential therapeutic agents[4,5]. Diabetes mellitus is characterised by chronic

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hyperglycemia[6,7], is associated with systemic low-grade inflammation that disrupts glucose and lipid metabolism, leading to a vicious cycle of metabolic perturbations and elevated susceptibility for cardiovascular complications and specific malignancies (e.g., colorectal, breast cancer, hepatic neoplasms)[8]. Inflammation as an endogenous, independent chronic disease and inflammation as a pathological driver play a hub role that provides the central links between diabetes, metabolic syndrome, and cancer risk[9,10]. Further, a greater number of studies have shown that inflammatory cytokines act as an overall fulcrum in the development process of these diseases. Cancer, in the same way, is now appreciated as not only a genetic or metabolic disease[11,12], but as one commonly promoted by a pro-inflammatory embracement aiding tumorigenesis, progression and metastasis[13].

The increasing burden of chronic diseases in the world has provided a stimulus for the development and application of plant-based therapeutics, owing to shortcomings and associated side effects, several synthetic drugs, as well as the quest for a more holistic, inexpensive model for care delivery[14]. Traditional pharmaceutical drugs often lack a multi-targeted and long-term safety control over disease, while natural plant-derived medicines provide an attractive choice for dealing with chronic diseases[15]. Phytomedicines of this type not only provide optimum management of the disease process, but also help to maintain a balance in overall physiology and are particularly applicable for long-term management/prevention of chronic diseases. Considerable evidence from epidemiological and experimental studies indicates that diets and drugs containing substantial levels of plant-derived bioactive compounds, such as polyphenols, flavonoids, carotenoids or alkaloids, possess potent antioxidant and anti-inflammatory properties combined with disease-modifying effects to ameliorate the pathogenesis/symptoms of chronic diseases (i.e., diabetes, cancer, cardiovascular disease or metabolic syndrome)[16,17]. Because of their multitarget action, such multiherbal formulations have the benefit over single and phytochemical evaluation of *A. ramosum* for the management of chronic diseases[18]. It emphasises its anti-inflammatory, anti-diabetic, antioxidant, anticancer and neuroprotective effects[19]. The present review serves as a bridge between traditional knowledge and modern research to investigate molecular mechanisms, recognition of main bioactive compounds, lacunas and future clinical applications due to their multi-component and multi-target actions, better tolerability, and improved safety during long-term use[20]. Such phytomedicines not only help control disease progression but also support overall physiological balance, making them suitable for long-term management and prevention of chronic diseases[21].

Abutilon ramosum, a well-known ethno-medicinal plant belonging to the family *Malvaceae*, has been shown to be a rich source of bioactive compounds having tremendous potential for the discovery of novel strategies for chronic diseases[22]. Aside from the above natural treasures, research on *A. ramosum* has been found very interesting due to its pharmacological applications, like anti-inflammatory, antioxidant and metabolic regulatory potential that have already been discussed with respect to its known congeners *A. indicum* and *A. theophrasti*[23]. Altogether, these results indicate that *A. ramosum* may be used as an effective therapeutic in long-term diseases and complications, such as diabetes, cancer, neurodegenerative and metabolic syndromes[24]. Although *A. ramosum* was commonly used in indigenous medicinal systems throughout Asia and Africa for a wide range of diseases or complaints, its scientific validation has remained limited, making curiosity-driven research imperative to explore its molecular and pharmacological mechanisms. Recent review articles and experimental studies with the genus *Abutilon* indicate that its phytoconstituents like flavonoids, iridoids, phenolics, steroids and alkaloids have a broad array of bioactivities; therefore, there is ample opportunity for isolation of new molecular lead compounds as well as elucidating their mechanisms of action[22,23]. There is also a growing interest in the species *A. ramosum* within the genus *Abutilon*, for its utility in chronic diseases. The present article offers a summary of the available ethnopharmacological and phytochemical literature, focusing on its traditional medicinal uses rather than on its bioactive chemical constituents uncovered to date. It reviews the experimental and clinical evidence in favour of its therapeutic potential, particularly in diabetes, cancer, inflammation and neurodegenerative diseases[22-25]. This review was specifically designed to summarise the ethnopharmacological information,

phytochemical fingerprint, pharmacological and phytochemical evaluation of *A. ramosum* for the management of chronic diseases. It emphasises its anti-inflammatory, antidiabetic, antioxidant, anticancer and neuroprotective effects. The present review serves as a bridge between traditional knowledge and modern research to investigate molecular mechanisms, recognition of main bioactive compounds, lacunas and future clinical applications.

2. Methods

The electronic database search was conducted in PubMed, Scopus, Web of Science, and Google Scholar to extract publications related to *A. ramosum* and the closely allied species *A. indicum* on chronic disorders. English publications up to 2025 were searched with related keywords, and *in vitro*, *in vivo*, and mechanistic molecular studies were taken into account, based on citation value. Information from the plant parts, extract types, doses, experimental models, IC_{50} values, molecular targets and mechanisms was analysed, assessing the therapeutic prospects of *A. ramosum* for chronic inflammatory and metabolic diseases with supportive evidence from phytochemically linked peers.



Figure 1. Botanical description of *Abutilon ramosum*.

3. Botanical Description of *Abutilon ramosum*

Abutilon ramosum (Cav.) Guill. and Perr. is a medicinal herb or shrub from the family *Malvaceae*, known for its uses both in medicine and ecology in tropical and subtropical regions[26]. The botanical features of *A. ramosum* are illustrated in Figure 1.

3.1 Taxonomy and Nomenclature

The botanical classification of *A. ramosum* is as follows:

- Kingdom: *Plantae*
- Phylum: *Streptophyta*
- Class: *Magnoliopsida*
- Order: *Malvales*
- Family: *Malvaceae*
- Genus: *Abutilon*
- Species: *Abutilon romosum* (Cav.) Guill. and Perr[26,27].

Common names: This species may be referred to by either of its synonyms in older literature: *Sida ramosum* Cav. and *Abutilon sidoides* Dalzell and A. Gibson[28].

3.2 Morphology

3.2.1 Description

Abutilon ramosum grows 1.25 to 2 meters high, an erect, suffruticose shrub with basal branching, the few lower parts turning woody[27]. Hairy most surfaces are densely covered with stellate hairs, sometimes longer and sticky, especially on the youngest leaves. The leaves are broadly ovate-cordate, sometimes shallowly three-lobed, with dark green above and a paler, softly tomentose underside 4–15 cm long; the margin is serrated. Stipules are thread-like, linear, and hairy. Flowers are yellow to orange, 1.5–2 cm in diameter, with 3–4 in the upper leaf axils. The corolla is tubular, and the stamens cohere to form a characteristic tube. The ovary is normally 7-celled, and the multiple reniform, glabrous seeds after fruiting[28].

3.3 Distribution

One species, *A. ramosum*, is found across much of tropical sub-Saharan Africa (from Namibia and Mozambique up to Sudan in the North), *A. biocarpum* on Madagascar, while other members are endemic to particular regions for instance north-western India as well as disturbed forests exists in the peninsular

Indian states like Karnataka, Kerala, Maharashtra and Telangana and abbots mead in Paraguay a dirty piece of land here[27]. The widespread distribution is an important feature of *A. ramosum*, which grows in a variety of habitats from Savannahs and open woodlands to disturbed sites and the roadside or margins of agriculture throughout Africa, the Indian subcontinent and Southeast Asia. It is well-suited to sandy, gravelly, and loamy soils and tolerates occasional periods of dryness. This aspect has helped expand its range from semi-arid regions in Southern Africa to various development plots across Asia and parts of South America. The wide ecological range indicates its adaptability and ethnobotanical availability[29].

All *Abutilon* species, including *A. romosum*, are used in traditional and ethnomedicine in both Africa and Asia. Leaves, roots, barks, flowers and seeds of *A. cepa* are widely used as indigenous healing remedies against a wide range of diseases[30]. Decoctions or powders of these parts are traditionally applied for digestive disorders, stomach complaints, fevers, wounds, inflammations and respiratory complaints. In other communities, the ground root in food and drink is taken for stomach problems as a mild tonic; leaves and flowers are applied externally on cuts, ulcers, boils, and taken internally for antitussive (cough suppressant) and anti-inflammatory[31]. The bark of *A. ramosum* is used for its fibre, and occasionally for poultices. The seeds as well as the flowers may be steeped in herbal infusions to obtain a mild analgesic or anti-inflammatory effect. These traditional uses also complement the wide range of ethnopharmacological applications reported for other *Abutilon* species, which have been validated by phytochemical studies to have anti-inflammatory, antimicrobial and wound healing properties[20,27,31].

4. Phytochemical Profile of *Abutilon ramosum*

As with other *Abutilon* spp., *A. ramosum* is rich in secondary metabolites that provide the plant with its pharmaceutical potential[24]. Different classes of phytochemicals like alkaloids, Flavonoids, glycosides, phenolics, tannins and polysaccharides, which demonstrate the presence in the leaves[32,33]. Flavonoids are the major phytoconstituents comprising quercetin, kaempferol, luteolin, apigenin, chrysoeriol and their glycosides. These compounds are related to the antioxidant, anti-inflammatory and cytoprotective effects of *A. taxon*[34]. As shown in Figure 2, *A. ramosum* contains various secondary metabolites such as flavonoids, phenolics, and glycosides. In the *Abutilon* species and related genera, we also isolated simple and complex nitrogen-containing alkaloids which might play a role in their antimicrobial, analgesic and antidiabetic activities as well[24,32]. Luteolin-7-O-β-glucopyranoside and chrysoeriol derivatives from the various parts of plants display remarkable antioxidant and anti-inflammatory properties[34,35]. Gallic acid, ferulic acid, and p-coumaric acid are found in stem and leaf extracts of *C. droserifolia* and play an important role in the antioxidant potential of the plant[24,36,37]. Tannins, an astringent and antimicrobial substance, are detected in significant concentration especially in the leaves and stems[38]. Furthermore, mucilage and other polysaccharides such as pectin are found throughout the plant body and contribute to a healthy immune system, digestion and wound healing[24,39]. The phytochemical constituents of *A. ramosum* and their chemical characteristics are shown in Table 1.

5. Isolated Phytoconstituents and Pharmacological Activities

Abutilon ramosum, demonstrating higher phytochemical contents compared to related *A. indicum* species which has been reported to possess flavonoids and phenolics such as quercetin, luteolin and chrysoeriol, along with gallic, caffeic and ferulic acids, along with sterols like β-sitosterol from leaves, flowers, and aerial parts. These compounds exhibit multitarget activities: antioxidant scavenging, anti-inflammatory, antidiabetic, and hepatoprotective. The isolated phytoconstituents are listed in Table 2.

6. Pharmacological Activities of *Abutilon ramosum* in Chronic Diseases

6.1 Anti-inflammatory and Analgesic Activity in *Abutilon ramosum*

Long-term stimulation of the immune system in chronic inflammatory diseases such as rheumatoid arthritis, osteoarthritis and inflammatory bowel disease leads to a persistent release of pro-inflammatory cytokines

Table 1. Shows the phytochemical constituents of *Abutilon ramosum* and their chemical characteristics

Sr. No.	Phytoconstituents	Key Compounds	Chemical Characteristic	References
1	Flavonoids	Quercetin, Kaempferol, Luteolin, Apigenin, Chrysoeriol	C6-C3-C6 framework, hydroxyl, and methoxy substitutions vary	9,32,36
2	Alkaloids	Hordenine, choline, and other nitrogenous bases	Typically, heterocyclic exact structures are unclear in species-specific studies	9,37
3	Glycosides	Luteolin 7-O-β-D-glucopyranoside, Chrysoeriol glycosides	Sugar moieties attached to glycosidic bonds	33,37
4	Phenolics	Gallic acid, Ferulic acid, p-Coumaric acid and derivatives	Simple phenolic acids with hydroxyl and carboxyl groups	33,36,37
5	Tannins	Gallotannins, ellagitannins, condensed tannins	Polyphenolic compounds with multiple phenol units, structures that vary widely	36
6	Polysaccharides	Mucilage polysaccharides	Complex carbohydrates, undefined, precise monosaccharide sequences	37

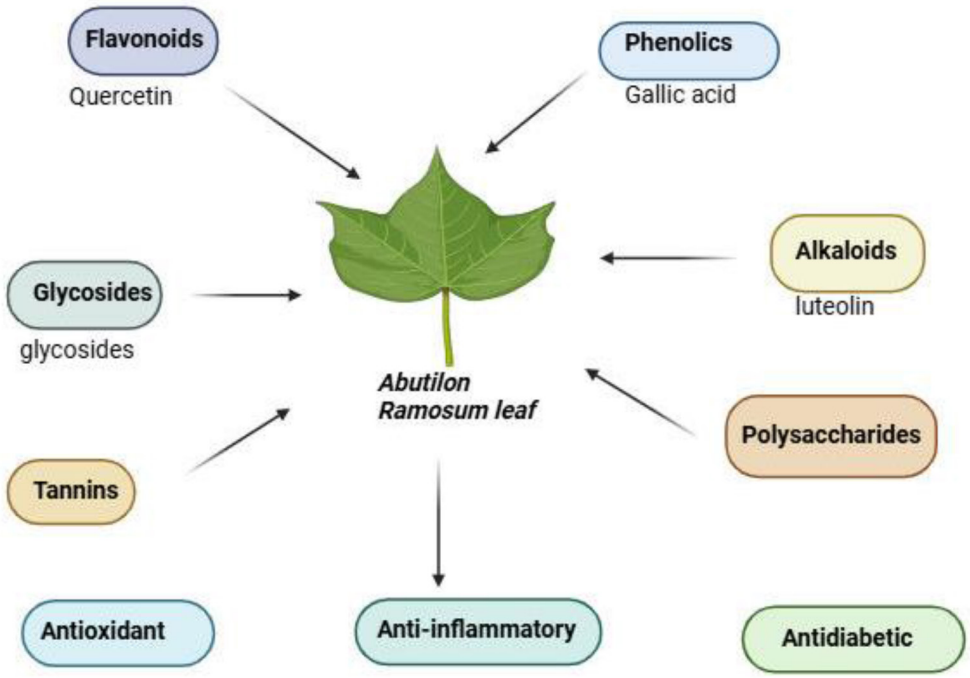


Figure 2. Major classes of secondary metabolites identified in *Abutilon ramosum*.

(TNF-α, IL-6) and nociceptive pain pathways, causing suffering over the course of life[55].

Abutilon ramosum and related species of *Abutilon* manifest excellent anti-inflammatory and analgesic effects, which directly act on the chronic inflammatory pathologies by suppressing prostaglandin synthesis, NF-κB signalling, and bradykinin-induced oedema in carrageenan models. Eugenol extracted from the plants of *Abutilon* has a double central and peripheral analgesic activity associated with musculoskeletal pain[56].

Abutilon ramosum could be a promising add-on therapeutic candidate for chronic inflammatory disorders, as it can modulate significant pro-inflammatory routes and display ibuprofen-comparable efficacy in the case of oedema, which provides opportunities for long-term use[22].

Abutilon ramosum shows a remarkable anti-inflammatory potential, having direct implications for chronic inflammatory disorders, which are associated with prolonged stimulation of prostaglandin, bradykinin

Table 2. List of the isolated phytoconstituents and pharmacological activities of *Abutilon ramosum*

Sr. No.	Phytoconstituents	Plant Parts	Isolation Method	Pharmacological Activities	References
1	Quercetin	Leaves, Flowers	MeOH extract → SiO_2 CC → HPLC	Antioxidant, anti-inflammatory, antidiabetic, analgesic	40
2	Luteolin	Flowers, Leaves	EtOH extract → Polyamide CC → Prep HPLC	Anti-inflammatory (5-LOX inhibition), hepatoprotective	41
3	Luteolin-7-O-β-glucopyranoside	Flowers	MeOH flower extract → Sephadex → HPLC	Hepatoprotective, antioxidant	41,42
4	Chrysoeriol	Flowers, Leaves	$CHCl_3$ fraction → Silica CC	Anti-inflammatory, hepatoprotective	43,44
5	Chrysoeriol-7-O-β-glucopyranoside	Flowers	MeOH extract → HPLC	Hepatoprotective	45
6	β-Sitosterol	Whole plant	Pet ether extract →CC →Crystallisation	Anti-inflammatory, hypolipidemic	46,47
7	Gallic acid	Aerial parts	Hydrolysis → HPLC	Antioxidant, anti-inflammatory	48,49
8	Caffeic acid	Leaves	EtOAc fraction → RP-HPLC	Antioxidant, antimicrobial	50,51
9	Ferulic acid	Leaves	MeOH extract → LC-MS	Antimicrobial, antioxidant	52,53
10	Eugenol	Whole plant	Steam distillation → GC-MS	Analgesic, anti-inflammatory	54

and cytokine-mediated pathways[56]. As *Abutilon* species are closely related as regards their phytochemical and pharmacological profile, the experimental evidence from *A. indicum* is likely in support of the medicinal value of *A. ramosum*. The ethanolic extract of *A. indicum* (250–750 mg/kg) significantly reduced carrageenan-induced paw oedema in rats, an established model for acute-to-chronic inflammation, at the equivalent levels to ibuprofen[57]. This effect is attributed to the inhibition of prostaglandin biosynthesis and bradykinin-mediated augmentation of vascular permeability processes that are relevant in arthritis as well as other inflammatory conditions[32,58].

Furthermore, the ethanolic and aqueous extracts of *A. indicum* significantly (100-200 mg/kg) inhibited up to 60% of acetic acid-induced writhing, when compared with having tail-flick latency significantly prolonged ($P < 0.001$)[59,60], which was also indicative that these phenolic and flavonoid constituents may act through peripheral opioid-like action on the central analgesic mechanism. Genetically, the effect of COX-2 inhibition on arthritis is to suppress the prostaglandin-forming reaction at the molecular level, and flavonoids inhibit NOS, COX-2 expression and proinflammatory cytokine (TNFα) production via their abilities to reduce NFκB and MAPK signalling pathways in LPS-induced chronic disease models[61,62].

The analgesic activity suggests that it may be used as an agent in the control of chronic pain. One of the main analgesic components was identified as eugenol, which demonstrated inhibitions (21-93%) in pain acetic acid-induced writhing model at doses of 10 -50 mg/Kg i.p.[63,64]. Central and peripheral analgesic effects were assessed by hot-plate and tail-flick tests, which are useful to study inflammatory as well as nociceptive pain from chronic musculoskeletal diseases[65]. The anti-inflammatory mechanisms of *A. ramosum* involve modulation of COX-2, NF-κB signalling, and pro-inflammatory cytokines, as illustrated in Figure 3.

6.2 Antioxidant Activity of *Abutilon ramosum* in Oxidative Stress–mediated Chronic Diseases

Chronic diseases associated with oxidative stress are caused by an imbalance of the production of ROS and antioxidant defences, culminating in lipid peroxidation, protein oxidation, and DNA damage. This brews pathogeneses like those seen in diabetes, neurodegenerative and cardiovascular diseases[66].

Antioxidant activities of species of *Abutilon* and their close relatives, like *A. indicum*. In some studies, it has been reported that extracts of the medicinal plants of *Abutilon* species possess antioxidant activity, and this ameliorates oxidative stress by scavenging free radicals

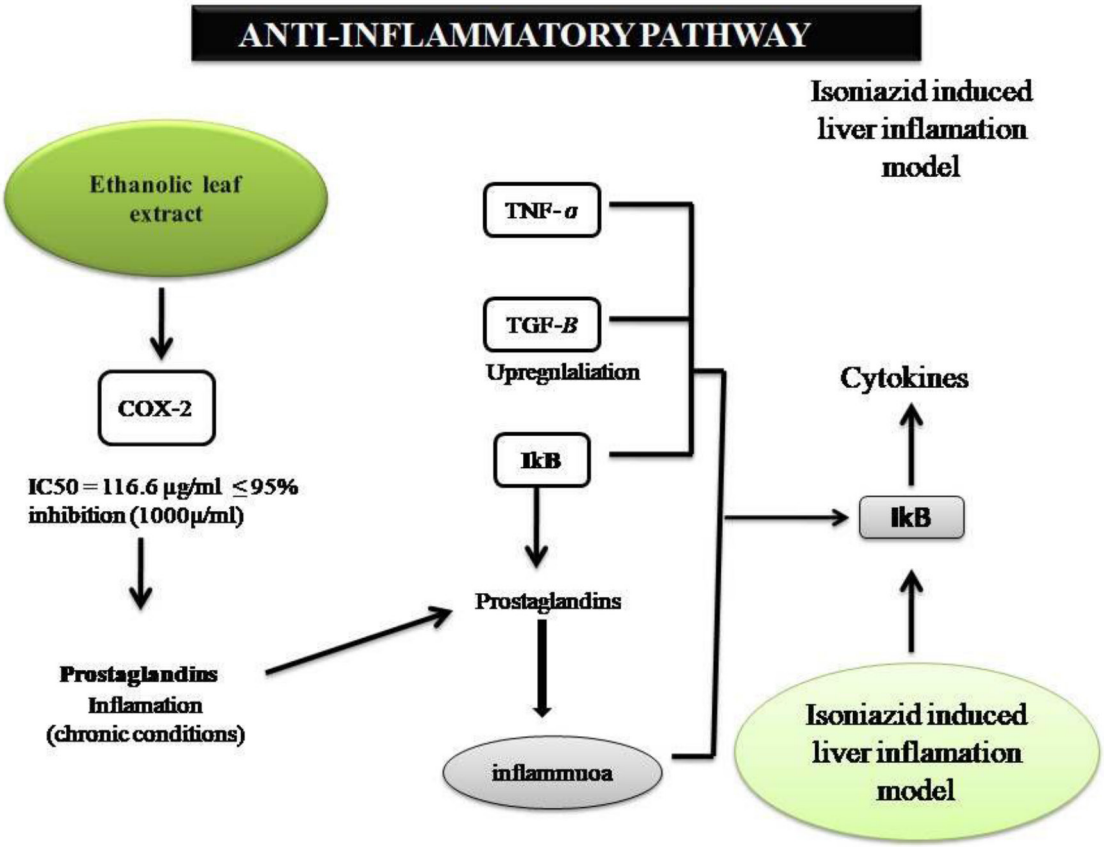


Figure 3. Schematic representation of the anti-inflammatory pathway of *Abutilon ramosum*.

(as evidenced by DPPH and ABTS tests), restoration of endogenous antioxidative enzymes such as SOD, peroxidase in the experimental models of oxidative stress like CCl_4-induced hepatotoxicity[67].

These antioxidant effects could dampen ROS-mediated activation of NF-κB and subsequent cytokine cascades (TNF-α, IL-6), which sustain chronic inflammation, validating the postulated use of plant antioxidants as adjuncts in preventing end-organ damage during long-term oxidative pathologies[68].

These antioxidant activities could preclude ROS-mediated activation of NF-κB and ensuing cytokine cascades (TNF-α, IL-6), which propagate long-term inflammation, thus providing a scientific basis for the proposed role of plant antioxidants as adjuncts in avoiding end-organ damage in long-standing oxidative pathologies. Due to the phytochemical similarity among different species of *Abutilon*, the antioxidant profile of *A. indicum* may furnish indirect list on the therapeutic potential of *A. ramosum*. (Radical scavenging activity of methanol extract of *A. indicum* roots showed the lowest IC_{50} (545.24 µg/ml) value, which was higher for its extracts derived from stems (IC_{50}=758.91 µg/ml) and leaves (1658.76 µg/ml), and fruits, IC_{50} (864.17). The greatest antioxidant potential of the root extracts was in accordance with their higher content of total phenolics (25.61 mg GAE/g), which shows that the high phenolic content is correlated with reducing power against oxidative stress–dependent chronic diseases[69].

The leaf extracts of *Abutilon* spp. exhibited significant radical scavenging activity against DPPH, ABTS, superoxide and hydroxyl with IC_{50} values (0.62 - 3.66) mg/mL. These activities might be closely associated with the high content of phenolics and flavonoids in them, because higher reducing ability would have resulted in better inhibition of lipid peroxidation, thereby protecting tissues from oxidative damage[70,71].

Flavonoids and phenolic compounds of *A. indicum* had significant antioxidant activity by scavenging free radicals in DPPH and NO assays, reducing intracellular ROS production and

preventing oxidative DNA damage. These extracts induced the Nrf2/Keap1 signalling pathway, resulting in an increase of endogenous antioxidant enzymes such as HO-1 and NQO1[62]. Activation of antioxidant systems also decreased mitochondrial ROS formation and lipid peroxidation. Furthermore, the cross-talk signalling with NF-κB suppressed nuclear translocation of NF-κB, connecting protective antioxidant defence to inhibit chronic inflammation[70,71].

Indeed, the ethanolic leaf extract of *A. indicum* (ELEAI) was able to ameliorate isoniazid-induced oxidative stress in rat liver by down-regulation of pro-inflammatory mediators[72], such as TNF-α, TGF-β and NF-κB and over-expression of inhibitory protein IκB that reduced ROS production and lipid peroxidation, which re-confirms the protective effect exerted by this extract against oxidative and inflammatory insults[73]. The antioxidant activity is mediated through ROS scavenging and activation of Nrf2/Keap1 signalling pathways (Figure 4).

6.3 Anti-diabetic Activity of *Abutilon ramosum* in Metabolic Disorders

Chronic hyperglycemia and insulin resistance in the setting of type 2 diabetes mellitus (T2DM) and metabolic syndrome cause microvascular complications as well as neuropathy, as they contribute to higher cardiovascular risk events via sustained glucose toxicity and defective β-cell function[74].

The extracts of *Abutilon* species, in particular *A. indicum*, effectively addressed diabetic complications through strong α-glucosidase and α-amylase inhibition (IC_{50} 13–74 μg/mL), as well as stimulation of glucose uptake in adipocytes and myotubes by activating PPAR-γ and reactivating the PI3K/Akt signalling network. Since the *Abutilon* species show close phytochemical resemblances, these results are taken as evidence in support of the antidiabetic effect of *A. ramosum*[75]. These effects impact the progression of diabetes by attenuating postprandial spikes, improving peripheral sensitivity and inhibiting oxidative/inflammatory cascades involved in the development of nephropathy, retinopathy

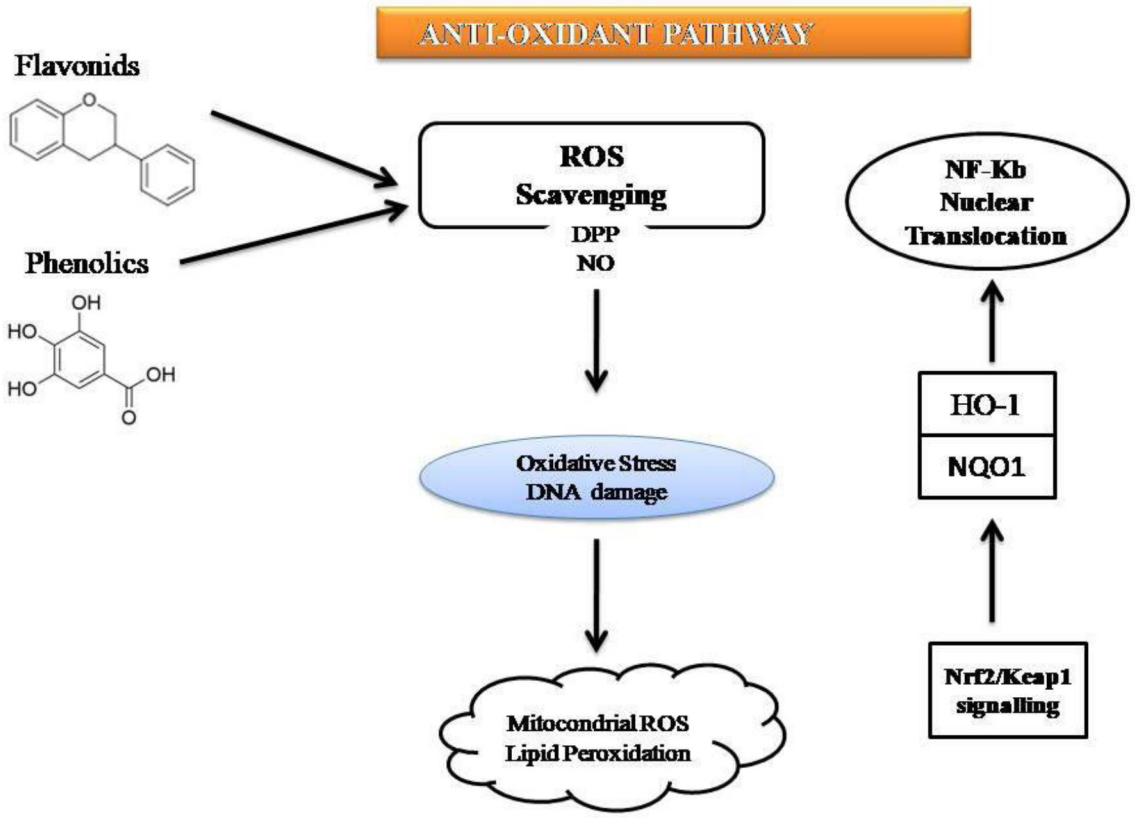


Figure 4. Schematic representation of the antioxidant pathway of *Abutilon ramosum*.

and atherosclerosis in the long-term metabolic syndrome[70].

Persistent hyperglycemia and insulin resistance characterise diabetes mellitus. Aqueous extracts of *A. indicum* suppressed postprandial blood glucose and adipogenesis in diabetic experimental animals[66,76]. These effects occur via inhibition of α-glucosidase and α-amylase, which leads to lower absorption of glucose in the small intestine[24,77].

The leaf extracts of *A. indicum*, especially the methanolic and aqueous fraction showed potent *in vitro* anti-diabetic activity by inhibiting the α-amylase and α-glucosidase, depending on concentration, with more than 70% inhibition at high concentrations (higher than 1000µg/mL) and delaying the carbohydrate digestion as well as intestinal glucose absorption, like acts as acarbose[78]. AIE of *A. indicum* potently suppressed the activity of α-glucosidase (IC_{50} = 74.15 ± 1.61 µg/mL) and that of α-amylase (IC_{50} = 13.41 ± 0.71 µg/mL), whereas it increased glucose utilisation by L6 myotubes and consumption by 3 T3-L1 adipocytes at IC_{50} values lower than 6.25 µg/mL, indicating the promising potential in postprandial hyperglycemia control[76]. The effects of aqueous extracts (doses 0.5-1 g/kg) on the plasma glucose in oral glucose tolerance tests conducted in diabetic rats occur more rapidly than those elicited by glibenclamide and involve stimulation of insulin secretion from pancreatic β-cells and INS-1E cells at 1-1000 µg/mL[79].

In addition, the activation of PPAR-γ and PI3K/Akt signalling pathways in 3T3-L1 adipocytes indicated improved insulin sensitivity. Polyphenolic constituents, such as gallic acid, have also contributed through the inhibition of carbohydrate-metabolising enzymes and promoting insulin secretion, positioning glucose metabolic enzymes in diabetes management as a major molecular target[68,80,81]. The LC–MS analysis of AIE showed the presence of gallic acid, stigmasterol, and riboflavin as bioactive compounds. These compounds regulate the PI3K/Akt pathway and insulin-independent glucose uptake, blocking insulin resistance in obesity- and diabetes-induced models[79].

6.4 Anti-arthritic Effects of *Abutilon ramosum*

Immune-inflammatory diseases in humans, such as rheumatoid arthritis (RA), are characterised by chronic synovial hyperplasia, autoantibody-mediated joint destruction and a slim immune balance with the disordering of Th17/Th1 cytokines[82]. The close enrichment of phytochemicals in different *Abutilon* species and the traditional use of *A. ramosum* for inflammatory conditions, coupled with experimental support from its counterpart species, *A. indicum*, demonstrates the anti-arthritic potential of *A. ramosum*, where another possible route to arthritic activity might also have been through the induction of liver enzymes against reported arthritis inflammation due to immunotherapy or due to Urticarial reaction. A: *In vitro* studies revealed that the aerial parts of *A. indicum* restrained protein denaturation up to 93.26% at a concentration of 1000 µg/mL, and this effect was better than the standard drug diclofenac sodium[82]. These pathways connect the pathogenesis of RA chronicity by interrupting cytokine storms leading to irreversible cartilage loss and disability, providing add-on immunomodulation[57,83].

Rheumatoid arthritis is an autoimmune inflammatory disease characterised by chronic inflammation in the joints, protein denaturation, dysregulation in immunity and overproduction of cytokines. Anti-arthritic potential of this plant is apparent by various experimental studies conducted on *A. indicum* (closely related species) that provided evidence for its effectiveness through modulation of inflammatory, immunological and molecular mechanisms, hence justifying the use of *A. ramosum* medicinally[84]. Aqueous extracts (0.1-0.25 g/ mL) also significantly protected against protein denaturation, protease inhibition and erythrocyte membrane stabilisation, indicating the anti-arthritis potential of *Ricinus* in traditional practices. Antiarthritic activity introduction Rheumatoid arthritis is a chronic inflammatory disorder marked by articular swelling, joint deformation, destruction of cartilage and bone tissue[76,85].

Anti-arthritic activities *A. indicum* extracts (100–250 mg/kg) displayed significant protection against protein denaturation, erythrocyte membrane lysis and protease at the Freund's complete adjuvant arthritis models, which resulted in a marked decrease of joint swelling as well as inflammatory markers equivalent to methotrexate treated animals[57,86]. Methanolic extract of the whole plant of *A. indicum* reduced paw volume

significantly on days 7 and 14 ($P < 0.01$) at the doses of 100 mg/kg, 200 mg/kg and 400 mg/kg with activity comparable with methotrexate (0.75 mg/kg). Strong *in vivo* antiarthritic activity against chronic joint inflammation was evidenced[87,88].

Immunological studies revealed enhanced humoral immune responses, increased delayed-type hypersensitivity reactions, and stimulation of phagocytic and neutrophil adherence activities. Regulation of Th1/Th2 cytokines, including IL-2, IL-4, TNF-α, and IL-6, suggests restoration of immune homeostasis, which is critical in the long-term management of autoimmune and chronic inflammatory diseases[89,90]. Aqueous extracts of *A. indicum* at 0.1–0.25 g/ml inhibited protein denaturation, protease activity, and erythrocyte membrane lysis *in vitro*, mimicking pathological processes in rheumatoid arthritis and validating traditional anti-arthritic uses[86]. Ethanolic leaf extract of *A. indicum* (ELEAI) at 250–500 mg/kg downregulated proinflammatory cytokines TNF-α and IL-6 via NF-κB pathway modulation in rat models, restoring anti-inflammatory IkB expression akin to silymarin[57].The anti-arthritic effects are associated with immunomodulatory pathways involving cytokine regulation and immune balance (**Figure 5**).

6.5 Antiulcer and Gastroprotective Activity of *Abutilon ramosum*

Peptic ulcers and chronic liver diseases, including hepatitis, are well-established with continuing oxidative stress, an increase in pro-inflammatory cytokines (TNF-α, NF-κB), and disruption of the mucosa, which eventually leads to gradual tissue damage over time[67]. *A. ramosum*, a folk remedy in gastrointestinal and hepatic disorders, is one of the phytochemically related plants to *A. indicum*, thus experimental findings of *A. indicum* also support the antiulcer potential of *A. ramosum*. *A. indicum* extracts caused a marked decrease (60–80%) in ulcer index induced by aspirin-, ethanol- and CCl_4-associated model via gastric acid secretion, mucin secretion and resolving antioxidant enzymes (SOD, catalase GPx) at par or higher to standard drug as esomeprazole[91-93]. They act directly on chronic pathologies of the gastrointestinal[90].

Gastrointestinal inflammation and hepatic damage were largely seen in correlation with oxidative stress and disturbed cytokine[94]. The aqueous and alcoholic extracts of *A. indicum*-replant, a closely related species to AR, caused a significant reduction in ulcer indices generated by aspirin-pylorus ligation, ethanol-, and acetic acid-induced ulcer models, attributed to a reduction in gastric acidity and volume along with

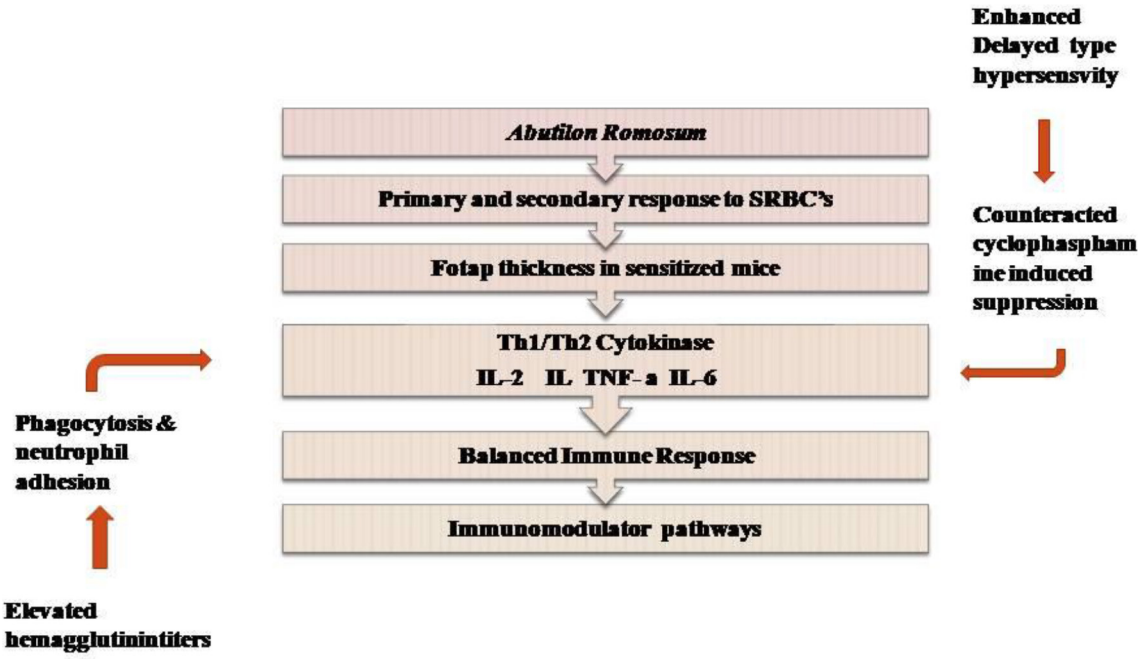


Figure 5. Schematic representation of the anti-arthritic pathway of *Abutilon ramosum*.

an enhancement of mucosal defence mechanisms[25,87]. Leaf extracts (and 400 mg/kg) also raised gastric pH and its mucus content ($P < 0.001$), indicating their gastroprotective effects through the modulation of aggressive and defensive factors[95].

In ethanol induced gastric ulcer model, ethanolic extracts of *A. indicum*, a plant closely related to *A. ramosum*, proved to have potential curative effects by means of a great reduction in ulcer area through mucosal protection and antioxidant activity compared to that of esomeprazole[88]. In isoniazid-induced liver injury models, ethanol leaf extracts of *A. indicum* regulated TNF-α, TGF-β and NF-κB expression and were found to raise the IκB level and attenuated inflammation/oxidative mediator pathways present that are responsible for hepatoprotective effect in chronic liver diseases[57,96,97]. The aqueous extracts (400 mg/kg) also showed anti-hepatotoxic activity with carbon tetrachloride and paracetamol-induced toxicity by normalising the levels of liver serum enzymes and by their potential to inhibit free radical formation[87,98].

Ethanolic *A. indicum* leaf extracts regulated hepatic antioxidant status in alcohol-induced liver damage condition and attenuated lipid peroxidation (TBARS) with the elevation of enzymes, including SOD, catalase, and GPx in rats[89,95]. Paracetamol-induced hepatotoxicity was significantly decreased by *A. indicum* methanolic extract silver nanoparticles, represented as increased cell viability and biochemical parameters in both *in vitro* and *in vivo* (rat) studies[99,100].

7. Conclusion

Abutilon ramosum is a medicinal plant with phytoconstituents such as flavonoids, phenolics, glycosides and polysaccharides that play roles in its antioxidant, anti-inflammatory, antidiabetic, anti-arthritic and gastroprotective properties. Pharmacological studies from closely related and at times even congeneric species, notably *A. indicum*, support its multi-target therapeutic value in the management of chronic diseases referred to as inflammatory, oxidative stress and metabolic disorders.

Although it has significant ethnomedicinal importance and promising preclinical evidence, species based scientific basis of *A. ramosum* is proving to be inadequate. Accordingly, bioassay-guided isolation of the active compounds as well as more sophisticated *in vivo* studies and high-quality clinical trials are required to identify its safety and efficacy for further development as a phytotherapeutic agent for long-term adjuvant treatment of chronic diseases.

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Author Contribution

Anjali Pandey: Conceptualisation, Visualisation, Writing – Original Draft; Priyanka Bansal: Methodology, Formal Analysis, Writing – Review and Editing; Bhavani Pantela: Validation, Resources, Data Analysis; Avijit Mazumder: Supervision, Project Administration; M. V. N. L. Chaitanya: Visualisation, Investigation. All authors have read and agreed to the published version of the manuscript.