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REVIEW ARTICLE

A Comprehensive Review on the Ethnopharmacological Potential of *Inula racemosa*

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Abstract

Inula racemosa, Pushkarmool or Indian elecampane, is a perennial herbaceous plant indigenous to the Himalayan region and various parts of Central Asia. It is classified within the Asteraceae family and is characterised by its tall stature, prominent foliage, and clusters of yellow blossoms. It has traditionally been a staple in *Ayurvedic* medicine due to its multifaceted therapeutic attributes, including expectorant, diuretic, and anti-inflammatory properties. Through chemical analysis, key bioactive constituents such as alantolactone and isoalantolactone have been identified, underscoring their medicinal significance. Emerging research underscores the potential of *I. racemosa* extracts in addressing respiratory disorders, gastrointestinal maladies, and inflammatory ailments. Nevertheless, comprehensive investigations are imperative to delineate its pharmacological mechanisms and potential adverse reactions.

Keywords: Antinephrotoxicity, Antithyroid Activity, Cardioprotective Activity

1. Introduction

Alternative medicine systems have been embraced for generations to lead healthier lives, particularly in India where Ayurveda is still away. *Ayurveda* is renowned for its holistic approach to managing various diseases, with *I. racemosa* standing out as a potent herb in both *Ayurvedic* and pharmaceutical practices[1]. The genus *Inula* boasts approximately 100 species across Asia, predominantly thriving in the alpine and subalpine regions of the Western Himalayas. These plants are grown around the edges of agricultural fields in India, especially those that grow wheat, barley, and buckwheat in Kashmir and the Himachal Pradesh Lahaul region. However, the delicate ecosystem that supports *I. racemosa* renders it critically endangered, primarily due to overexploitation, habitat destruction, and competition. In *Ayurveda*, *I. racemosa* referred to as Puskarmula, has long been utilized for its therapeutic properties against conditions such as Saws and Hikka. Recent research has unveiled its potential as an anti-inflammatory, cardiotonic, carminative, thermogenic, and expectorant agent[2,3].

2. Pharmacognostic Investigation

2.1 Scientific Classification

Kingdom – *Plantae*
Phylum – *Magnoliophyta*
Class – *Magnoliopsida*
Order – *Asterales*
Family – *Asteraceae*
Tribe – *Inulae*
Genus – *Inula*
Species – *Inula racemosa*

2.2 Vernacular Names

English – Indian elecampane, sun spear
Hindi – *Pokharmul*
Sanskrit – *Puskaramula, kasmira, padma, sugandhikam*
Telugu – *Pushkaramulamu*
Gujarati – *Pokharmul*
Kannada – *Puskarmul cashmini*

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Malayalam – *Puskkarmulam*
Marathi – *Pushkarmul*
Tamil – *Puskarmulam*

2.3 Synonyms

Pouskara, Bheda, Ciram, Jiham, Tirtha, Dhira, Padma, Puskarahava, Brahmatirtha, Vatahva, Viram, Swasari, Sugandhikam, Mula, Pushkarjata[4].

2.4 Description

Inula species encompass annual, biennial, or perennial herbaceous plants, exhibiting erect or prostrate growth habits, typically adorned with a variable covering of hair, although occasionally glabrous as in kalapani. Stems are generally well-developed, frequently branched, although occasionally simple, and in rare instances, exceptionally short as seen in *Inula rhizocephala*. Leaves are simple, arranged alternately, and may be sessile or possess petioles. They sometimes form basal rosettes and exhibit varying degrees of hairiness. Capitula, or flowerheads, are solitary, terminal, or clustered in corymbs or panicles, presenting heterogamous florets that can be radiate, disciform, or occasionally discoid[5]. The involucral bracts are arranged in multiple overlapping rows, with outer bracts typically herbaceous and often foliaceous, while inner bracts are usually rigid and may possess a scarious texture. The receptacles are generally flat or slightly convex, with a smooth or somewhat alveolate surface and lack paleae. Ray florets are female, with radiate to mini radiate configurations, occasionally missing, and typically terminating in 2 or 3 teeth. Disc florets are hermaphroditic, characterized by tubular yellow corollas with five lobes. The anthers exhibit caudate morphology, featuring branched sagittate tails with acute or obtuse apical appendices. Endothelial tissue within the anthers is radial, with filament collar cells typically longer than wide (Figure 1). Pollen spines are primarily acute, occasionally rounded, as observed in *I. rhizocephala*. The style is bifid, with style branches possessing acute sweeping hairs on the abaxial surface, which do not extend to the furcation. Stigmatic lines are confluent apically but remain separate at the base. Cypselae, or achenes, are shorter than the corolla and display ellipsoid or cylindrical shapes, often with subterete angles and slight to distinct ribbing. They are composed of sclerenchymatous tissue and may be glabrous or pubescent. Each epidermal cell typically contains a single elongated crystal. Pappus bristles are arranged in 12(3) series, exhibiting varying degrees of scabridity to barbellate texture, and persist beyond fruit maturation[6].

2.5 Quantitative Microscopy

The cross-section of a fully formed root had a mostly round but undulating shape, which may be attributed to the existence of rhytidomes (Figure 2). The phelloderm is composed of a narrow area, followed by a compact cortical region that progressively transitions into a wider parenchymatous zone that includes the phloem. The phloem area was clearly distinguished from the xylary zone by a wavy but easily noticeable cambial ring, which could be identified by its location[7]. Significantly, the exterior region of the xylem and the tissues located outside the cambium were characterized by the abundance of secretory canals, as seen in Figure 2. Within the phelloderm, there were detected two to four layers of cells with thick walls that were suberized.

Some spreading medullary rays could also be seen in this area from time to time. The forms of these cells ranged from rectangular to sub-rectangular or trapezoid to triangular, and they were filled with a dark brown, irregular substance, as shown in Figure 2. When first seen, the cells were mostly rectangular and sometimes trapezoidal. But when they were dried out, they changed into deformed shapes with different patterns. The size of these cells changed from the edges to the middle, with the edges being bigger than the middle. Along with well-developed schizogenous secretory tubes, uneven cracks



Figure 1. *Inula racemosa* plant.

and holes were seen in the area, as shown in Figure 2. From a Pharmacognostic point of view, the pericycle could not be identified. It wasn't clear where the cortex ended and the phloem began. The phloem was spread out in patches within a large area of irregular parenchymatous cells. As shown in Figure 3, schizogenous secretory tubes were also seen in this area[8].

Figure 4 shows that in the middle part of the xylary core, there was a tight structure made up of vessels and sclerenchyma that had no parenchymatous parts at all. On the other hand, the outside of this core had a lot of tissue and many schizogenous secretory tubes that went through it. This edge area could be broken down into three circular zones (Figure 2), and each one had its patterns of vessel distribution.

Zone I: Consisted of small vessels, either solitary or arranged in groups of 2-3.

Zone II: Comprised of large vessels, either grouped with or without adaxial patches of sclerenchyma.

Zone III: Showed radial arrangements of small vessels without any accompanying sclerenchyma.

This detailed observation provides insight into the anatomical structure of the root section, emphasizing the composition and organization of its various tissue layers and vascular components[9].

2.6 Powder Characteristic

The powder exhibited a brown hue, possessed an acrid taste, and felt coarse to the touch. Even when squeezed between two blotting sheets, it didn't quickly get greasy. If the paper was left out in the open for too long or warmed slightly, it would show obvious oil stains. In the presence of UV light, the powder did not fluoresce; but, when dissolved in water, different organic solvents or mild potassium hydroxide solutions, its extracts showed green fluorescence. Mild foaming was seen when the powder was shaken with water means the presence of saponins. As it stood, the mixture split in two: a layer of clear brown liquid on top and a layer of solid, greyish-brown particles below.

The powder displayed many diagnostic features when examined under a microscope, as shown in Figure 5 and Figure 6. These included thick-walled fibre pieces with both round and pointed ends and a very narrow central lumen, thick-walled but non-lignified cells slightly longer than broad and with simple, brown resinous masses of various shapes and sizes, rectangular parenchymatous cells, fragments of fibres with thick walls but rather broad central lumens and pointed ends, rectangular cells with an irregular pattern of thickening of their walls[10].

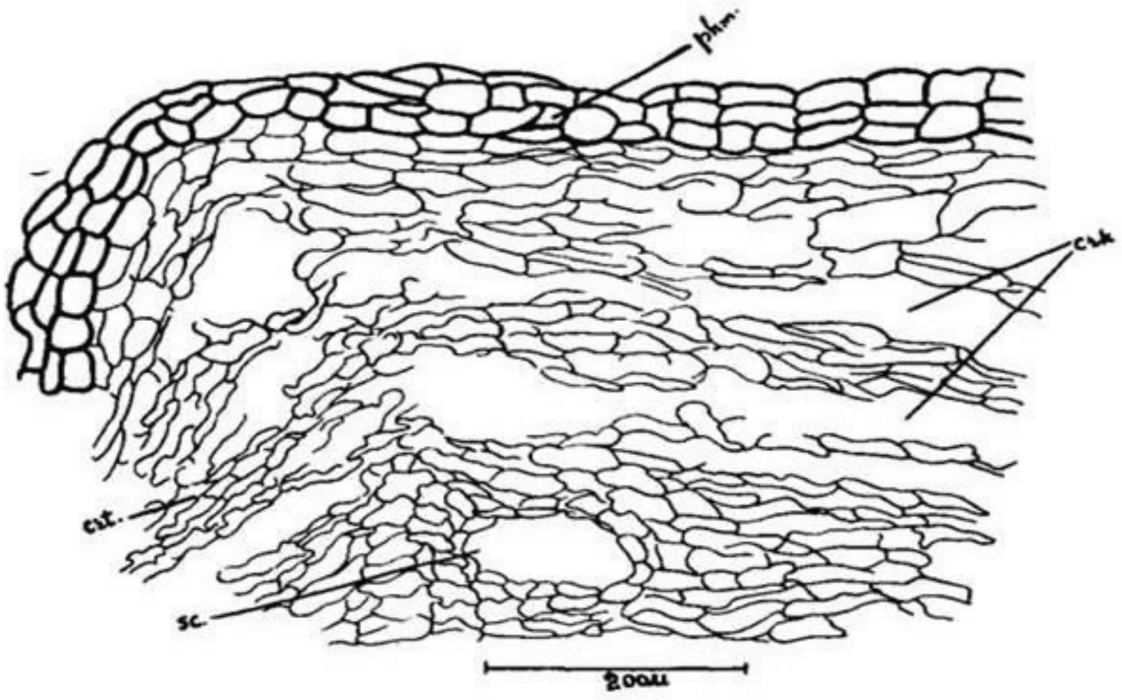


Figure 2. T.S. of root (*I. racemosa*).

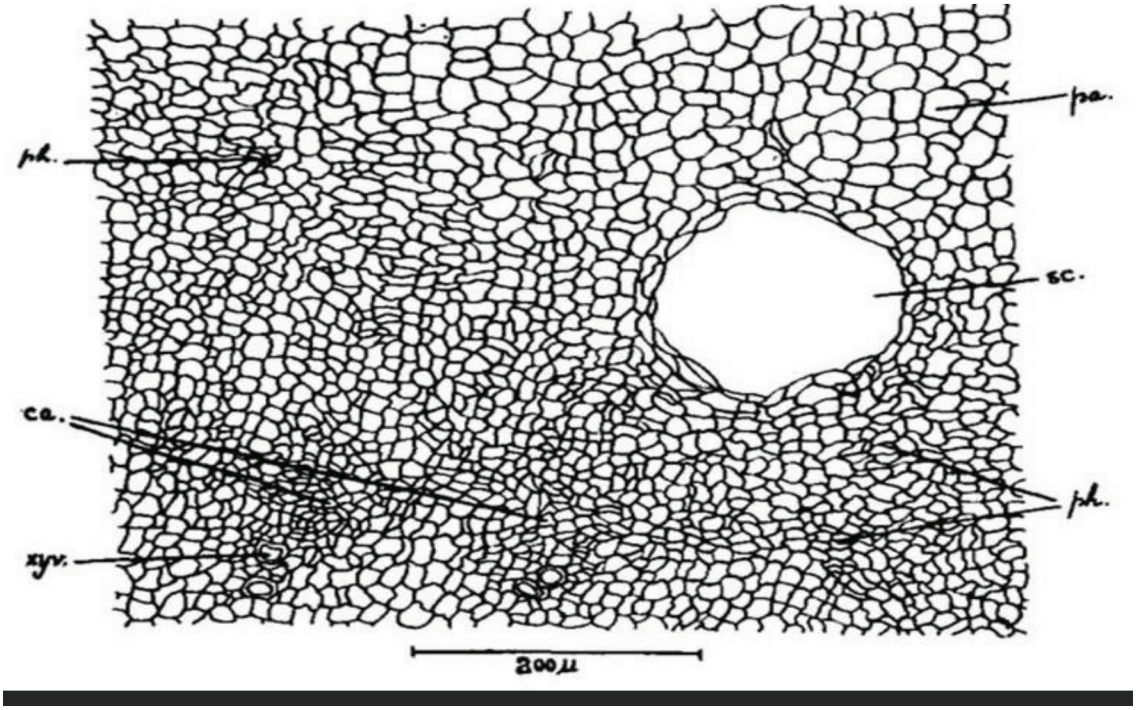


Figure 3. Cortex of root (*I. racemosa*).

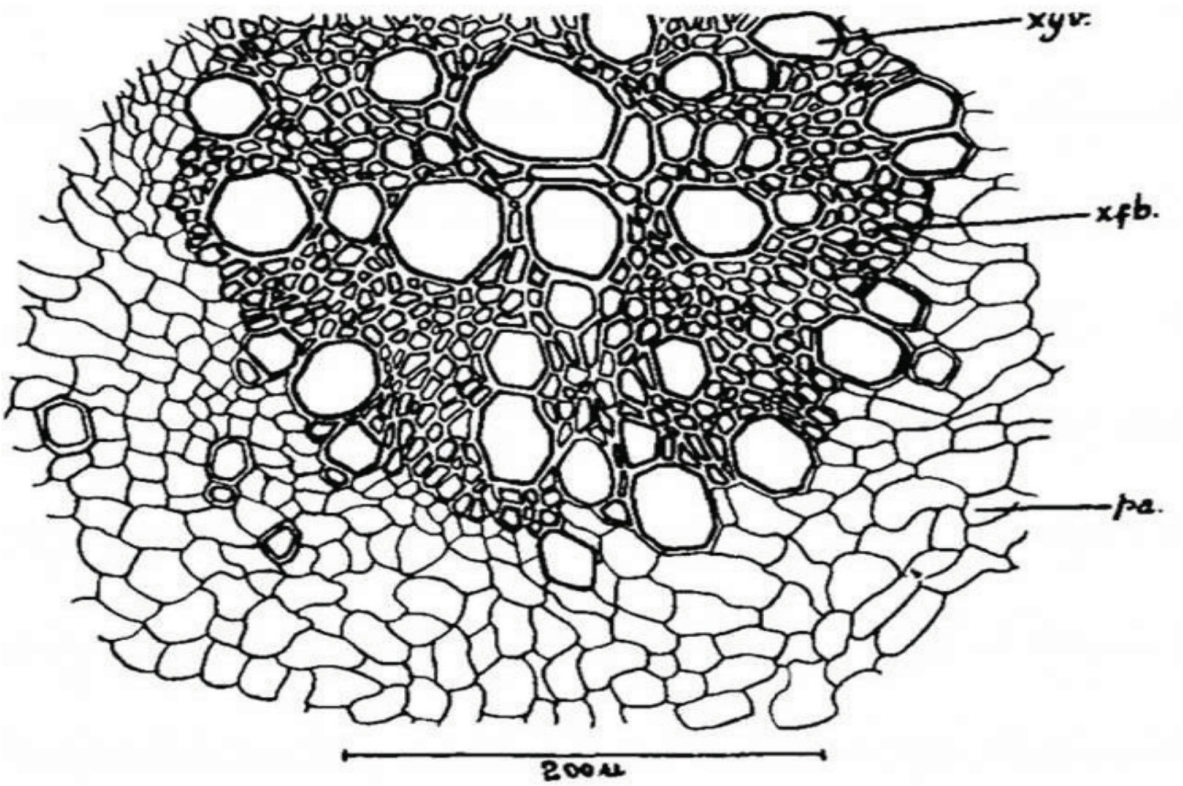


Figure 4. Midrib region of root (*I. racemosa*).

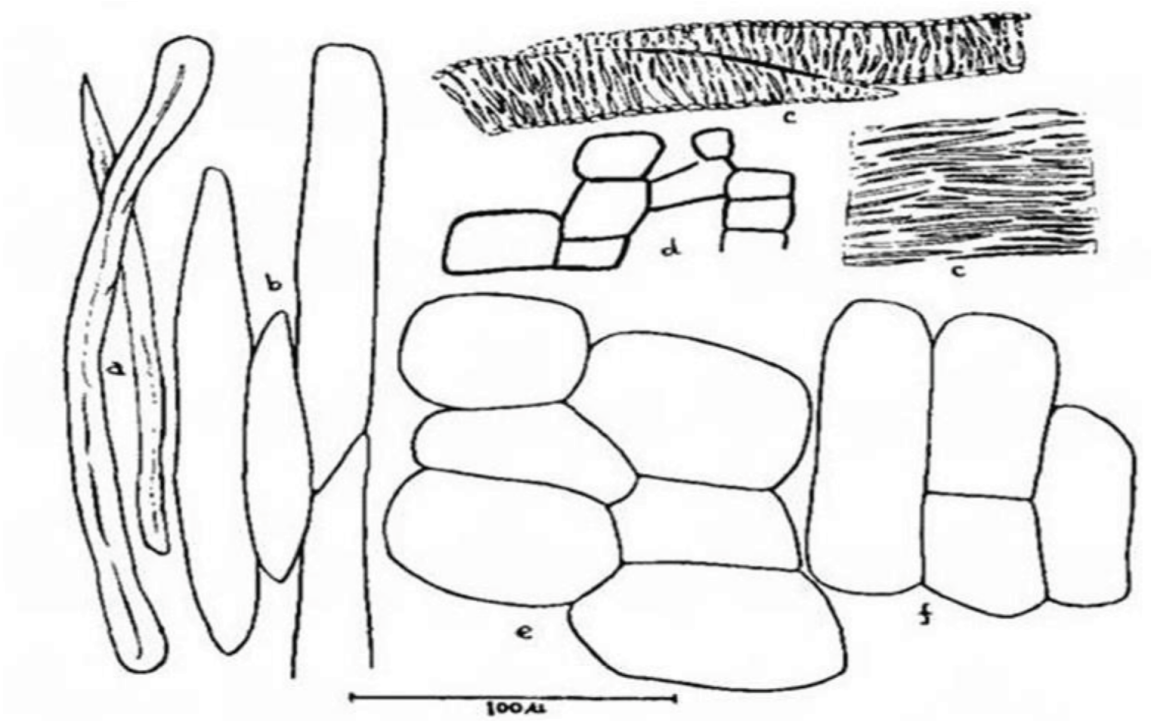


Figure 5. Powder characteristics of root (*Inula racemosa*)[10].

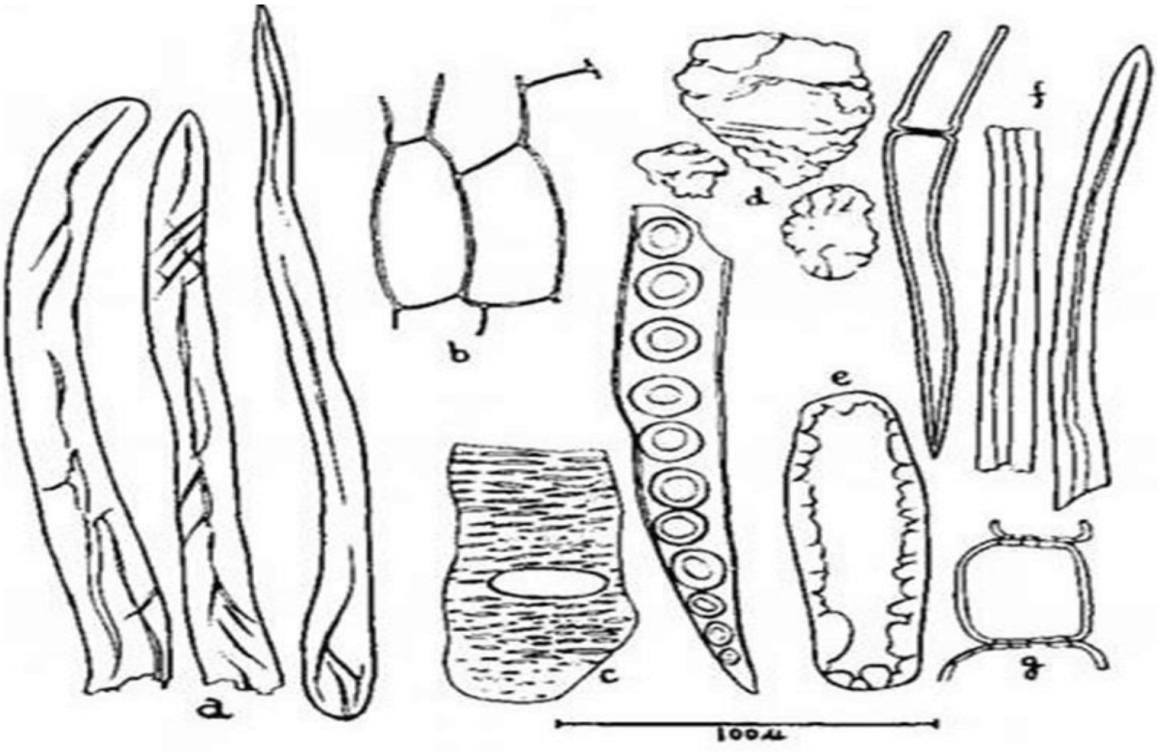


Figure 6. Powder characteristics of root (*I. racemosa*).

3. Chemical Constituents

The chemical constituents are represented in Table 1.

4. Ethanopharmacognosy

Asteraceae family member *I. racemosa* Hook. F. is an Indian native plant with a long history of therapeutic use. Commonly known as *Pushkarmula*, it holds a significant place in *Ayurvedic* scriptures and is mentioned in various texts. A few names for the plant include *sulahar*, *sughandhika*, *kasari* and Sage Charaka distinguished it as *hikkanigrahana* for hiccups and svasahara for asthma. In particular, it has a stellar reputation as a treatment for pleurisy (*parsvasula*). Not only can *Pushkarmula* help with respiratory problems, but it also shows signs of anti-inflammatory, antianginal, hypoglycemic, analgesic, and antibacterial effects. Research in various animal models has provided empirical support for several of these ethnomedicinal properties. This article aims to gather and summarize all the scientific research on the ethnopharmacology of *I. racemosa*. It includes studies on the bioactivity of extracts and specific compounds obtained from the plant, as well as studies on its isolated phytoconstituents[20].

Table 1. Chemical constituents of *I. racemosa*

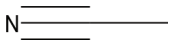
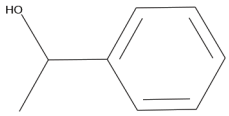
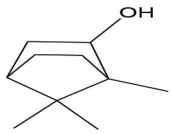
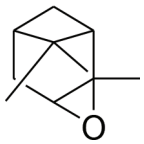
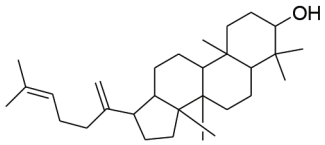
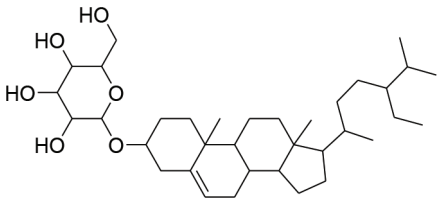
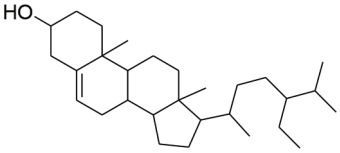
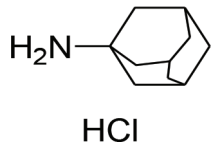
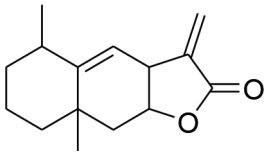
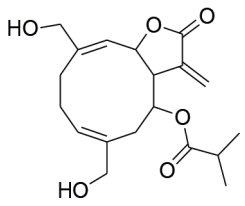
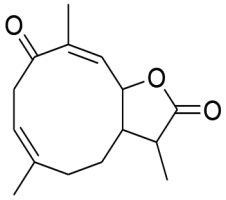
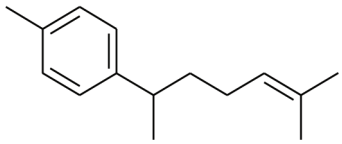
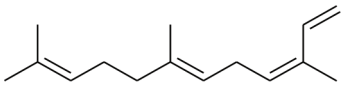
S. No.	Compound Name	Structural Unit	Mol. Formula	Chemical structure	References
1	Benzoid	Acetonitrile	CH3CN		11
		Phenyl ethanol	C8H10O		
2	Monoterpene	Borneol	C10H18O		12
		Para-pinene	C10H16O		
3	Triterpene	Dammara-20-24-dien-3-beta-ol	C32H52O2		13
4	Steroid	Daucosterol	C35H60O6		5
		Beta Sitosterol	C29H50O		14

Table 1. Continued...

5	Sesquiterpene	Alantodine	C10H18ClN		15
		Alantolactone	C15H20O2		16
		Alantolides	C19H26o6		17
		Costuslactone	C15H20O3		18
		Curcumene	C15H22		19
		Alpha-Farnesene	C15H24		12

5. Pharmacological Review

5.1 Antiallergic Activity

Inantiallergic study researcher used albino rats as experimental models of type I hypersensitivity to examine the possible antiallergic qualities of the alcoholic extract made from the root of *I. racemosa*. A continuous heat extraction method produced the alcoholic extract. When given intraperitoneally (IP), the extract's LD_{50} was found to be 2100±60 mg/kg[21]. A range of *I. racemosa* dosages was used in the evaluation of protection against egg albumin-induced Passive Cutaneous Anaphylaxis (PCA), either as a single dose or as intraperitoneally or orally spread over seven days. Compound 48/80 was used as the degranulation agent in research on mast cell degranulation, with a comparable dosing regimen. When *I. racemosa* was administered intraperitoneally or orally, it had a notable protective effect against PCA caused by egg albumin[22]. Moreover, when taken as a single dosage, the alcoholic extract of *I. racemosa* showed protection against compound 48/80-induced mast cell degranulation equivalent to that of disodium cromoglycate. Notably, the seven-day drug treatment regimen exhibited superior protection compared to intraperitoneal disodium cromoglycate. These findings collectively indicate the potent antiallergic properties of *I. racemosa*[23].

5.2 Antibacterial Activity

The study aimed to assess the potential medicinal properties of *I. racemosa* Hook and *Phytolacco accinosa roxb*, both of which are endangered medicinal plants native to the Kashmir valley. Specifically, the antimicrobial activity of these plants was evaluated

using the disc diffusion method. The crude extracts obtained from the roots of these plants exhibited significant antimicrobial activity against a majority of the tested organisms. The findings showed that the hydroalcoholic root extracts of *Phytolacca accinosa* and *I. racemosa* showed concentration-dependent inhibitory zones against a range of bacterial strains, including Gram-positive and Gram-negative. These results indicate that *Phytolacca accinosa* and *I. racemosa* may have antibacterial potential due to the presence of bioactive chemicals in their root extracts. Further research is warranted to identify and isolate these bioactive compounds and explore their therapeutic potential in the treatment of chronic and infectious diseases[24,25].

5.3 Anti-pyretic Activity

For a long time, *Pushkarmool* or *I. racemosa* Hook. The family has been regarded as a strong Asteraceae plant with remarkable therapeutic properties, especially for cardiovascular and pulmonary health[26]. From its original usage to its modern appeal, this article provides a brief outline of its historical relevance in medicine. Drawing from a wide range of sources including original *Ayurvedic* scriptures, classical texts, and scientific databases, the pharmacological, biochemical, and clinical studies of *Inula*'s natural compounds are comprehensively reviewed. Its widespread use in *Ayurvedic* medicine, especially as a treatment for fever (*Jwara*), is highlighted. Supported by *in vitro* and *in vivo* research showing its antibacterial, anti-inflammatory, antioxidant, and antifungal activities, this article meticulously compiles and analyzes a variety of references to illustrate *Inula*'s potential as a strong antipyretic. Research on the antipyretic qualities of *Pushkarmoola* should be prioritized in light of the historical data that has been provided. This will allow academics to fully understand the potential advantages of this plant in treating different forms of fever, or jwara[27].

5.4 Toxicity Assessment

An extensive study was conducted to assess the insecticidal, antifeedant, and repellent properties of various fractions of a chloroform extract from the root of Pushkarmoola (*I. racemosa* Hook) f. (Asteraceae), as well as its non-polar and polar components. The adults of *Tribolium castaneum* Herbst were tested using broken wheat grains as test substrates. The results of the bioassays were striking; at a concentration of 15 mg/g, the non-polar fractions caused mortalities on the 11th day, the polar fractions on the 15th day, and the root extract on the 19th day. The order of toxicity was determined as petroleum ether fraction (non-polar)>acetonitrile fraction(polar)>chloroform root extract. The insecticidal bioassay demonstrated concentration and time dependency, indicating a significant impact of both factors on efficacy. Conversely, the repellent assay remained independent of duration but exhibited variation with concentration. Within 5 hours, the root extract concentration of 15 mg/g produced the highest level of repellency. In the antifeedant study, weight loss in treated grains (0.27%) was found to be non-significant compared to the control (0.36%) after 21 days of treatment, indicating a significant antifeedant effect. The research found that out of all the fractions evaluated, the non-polar *I. racemosa* fraction was the most poisonous and also possessed repellent properties. These findings contribute to our understanding of the insecticidal and repellent potential of *I. racemosa*, suggesting its possible applications in pest management strategies[28].

5.5 Hepatoprotective Activity

To protect the livers of rats against paracetamol (PCM) damage, this research sought to identify an ethanolic extract of *I. racemosa* roots (IRE) may have any effect. The experimental design included seven days of pretreatment with Silymarin at a dose of 100 mg/kg/day, followed by the eighth day of oral administration of PCM at a dose of 3 g/kg b.wt. We killed the animals for further study after collecting blood samples from the retro-orbital plexus 24 hours after the previous PCM dose. We measured liver weight, relative weight, alanine aminotransferase, aspartate aminotransferase, total protein liver histology, and other parameters. Findings indicated that, when tested against PCM-induced liver damage, the ethanolic extract of *I. racemosa* roots exhibited liver-protective properties comparable to silymarin[29]. *I. racemosa* roots were the first to have gallic acid identified, which might mean that it is a component of IRE. Due to the inclusion of gallic acid, IRE was shown to have a hepatoprotective effect.

In conclusion, this study provides scientific evidence supporting that the extract from the roots of *I. racemosa* has hepatoprotective effects. Potentially mediated by the presence of gallic acid, validating its traditional use in *Ayurvedic* literature for liver health[30].

5.6 Antithyroid Activity

In a comparative study, rats given 400 mg/kg of *Saussurea lappa* root extract for 14 days or the same dose of *I. racemosa* root extract for 20 days were used to study thyroid function stimulation. Thyroid tissue histological analysis showed signs of thyroid activation in the two groups receiving therapy, though the observed efficacy was not as high as other *Ayurvedic* or herbal remedies for hypothyroidism. These findings suggest that while both *Saussurea lappa* and *I. racemosa* root extracts may possess some degree of thyroid-stimulating activity, their effectiveness in this regard may be limited in comparison to alternative treatments[31].

5.7 Antiasthmatic Activity

Inula racemosa, also known as "*Pushkaramula*" in India's traditional medical system, has garnered attention for its therapeutic properties. The roots of this plant are characterized by their bitter, acrid, thermogenic, aromatic, and stimulant nature. In addition to being a febrifuge, expectorant, bronchodilator, aphrodisiac, antiseptic, alexipharmic, deodorant, anti-inflammatory, carminative, and tonic property[32]. Traditionally employed to address conditions associated with vitiated *kapha* and *vata*, as well as to treat foul ulcers and wounds, it has also found application in the management of asthma-like conditions within *Ayurvedic* practices in India. Motivated by its traditional use, we undertook an evaluation of the pharmacological actions of test extracts derived from *I. racemosa* on various aspects relevant to asthma[33]. Bronchoconstriction, mast cell degranulation, and allergy-related alterations in vascular permeability were examined using *in vitro* and *in vivo* animal models. From air-dried roots, extracts were produced using ethanol (95% concentration), water, and petroleum ether (60-80°C warming range). At 4 and 10 mg/ml concentrations, in particular, the petroleum ether extract showed strong antagonistic effects on histamine-induced contraction. More so, preparations using goat tracheal chains showed a dose-dependent contraction. To reduce eosinophilia, the petroleum ether extract demonstrated significant control, notably at doses of 50 and 100 mg/kg IP. Similarly, it exhibited a dose-dependent inhibition of milk-induced leucocytosis, indicative of its adaptogenic potential.

Furthermore, pre-treatment with the petroleum ether extract significantly protected against clonidine-induced mast cell degranulation, supporting its potential as a mast cell stabilizer. This effect was particularly notable at a dose of 100mg/kg IP. Finally, the extract demonstrated a significant alteration in capillary permeability, further supporting its potential role in addressing asthma and related conditions.

In conclusion, the results of our study underscore the pharmacological potential of *I. racemosa* in addressing the immunological, physiological, and biochemical aspects of asthma and related disorders[34,35].

5.8 Antiarthritics Activity

The Indian medicinal plant *I. racemosa* goes by more than just *Pushkarmool*; it's also known as *Pokharmul* in Gujarati and Hindi, *Puskarmula* in Kannada, and Indian elecampane in English. In this work, we used *in vitro* methods, such as the protein denaturation inhibition test and HRBC stabilization, to investigate the anti-inflammatory properties of *I. racemosa* extract. As a rule, diclofenac sodium was prescribed. The findings showed that the anti-inflammatory effects were rather encouraging. The inflammation caused by the injection of Freund's Complete Adjuvants (FCA) into the plantar surfaces of animals resulted in the development of arthritis. In a paw edema model, mice were given 100 mg/kg of the extract orally for 28 days coupled with Diclofenac sodium (10 mg/kg), and dosages of 200 mg/kg were also given. There were several biochemical markers measured, including Erythrocyte Sedimentation Rate (ESR), blood cell, red blood cell, haemoglobin, body weight, paw edema, and joint diameter.

Overall, the findings suggest the potential anti-inflammatory action of *I. racemosa* extract, indicating its therapeutic promise in managing inflammatory conditions such as arthritis[36].

5.9 Antifungal Activity

The current investigation centred on the separation of isoalantolactone, alantolactone, and sesquiterpenoid

lactones derived from the *I. racemosa* root eudesmanolide type. These chemical transformations were performed on these compounds using a variety of reagents. After everything was synthesized and isolated, the antifungal activity of each molecule was tested *in vitro* using the spore germination inhibition technique against *Alternaria triticina*, *Fusarium moniliforme*, and *Dreschlera oryzae*. The investigation aimed to elucidate the structure-activity relationships governing the antifungal function of sesquiterpene lactones. Notably, isoalantolactone and its derivatives exhibited higher toxicity in contrast to the derivatives of alantolactone. Bromoform derivatives were the most effective of the produced chemicals, whilst methoxy derivatives were the least effective. The three test fungi showed encouraging antifungal activity against all chemicals in the results, with ED50 values of 400 ppm. These findings underscored the potential of sesquiterpenoid lactones, particularly isoalantolactone and its derivatives, as viable candidates for further exploration in the development of novel antifungal agents[37].

5.10 Ischemic Heart Disease

The 200 patients with ischemic heart disease participated in a trial where the antianginal effects of hypolipidemic potential *Commiphoramukul* and *I. racemosa* were combined synergistically. Evaluating the combo therapy's effectiveness in reducing chest discomfort and enhancing functional status was the goal. The research noted that normal Electrocardiogram (ECG) rhythms had returned, coupled with notable improvements in the grades given to preoperative dyspnea and precordial discomfort.

Moreover, there were significant reductions in triglyceride, cholesterol levels, and total lipid, which supports the positive benefits of the combination medication regimen. Additionally investigated were mechanistic explanations for the medication combination's effects. The Guggul's cardioprotective qualities have been linked to the reported decrease in the cardiac risk connected to Antiischemic medication. Furthermore, the capacity of *Pushkarmool* to enhance prostaglandin E1-like enhancing properties and restore post-exercise ECG were thought to be important causes of the reported therapeutic results. The combination therapy was shown to be effective in controlling ischemic heart disease overall, and the study's results suggest that this method might be a complete one that addresses both angina symptoms and lipid metabolism[38].

5.11 Cardioprotective Activity

Many tests have been conducted to assess *I. racemosa*'s adrenergic beta-blocking ability, and the results have been encouraging, especially for individuals who have been diagnosed with ischemic heart disease already.

Notably, Interestingly, T-wave inversion and ST-segment depression shown in the post-exercise ECGs of affected persons have been found to be significantly reduced by the administration of *I. racemosa* root powder. Research on animals has provided more insight into its workings, showcasing the quick actions of *I. racemosa* root petroleum ether extract Within only 75 min of oral administration, this extract significantly reduced the levels of glucose and plasma insulin in albino rats. Furthermore, it greatly reduced the hyperglycemia that rats produced when given adrenaline. The extract may also be used as a beta-blocker since it showed significant negative chronotropic and negative inotropic effects on the frog heart.

In human trials, a combination therapy involving *I. racemosa* and *Commiphora mukul*, commonly known as *Pushkara guggul*, showcased efficacy in alleviating chest pain and dyspnoea associated with angina. This synergistic effect underscores the therapeutic promise of *I. racemosa* in cardiovascular health, suggesting that its adrenergic beta-blocking properties could be attributed to one or more of its constituent compounds. These collective findings not only underscore the pharmacological potential of *I. racemosa* but also highlight its relevance in managing cardiovascular conditions, offering new avenues for therapeutic interventions[39].

Inula racemosa was shown to have cardioprotective properties against myocardial ischemia-reperfusion damage in research involving male Wistar albino rats. Increases in glutathione peroxidase, catalase, and superoxide dismutase were among the markers used to demonstrate that treatment with *I. racemosa* markedly restored the myocardial antioxidant state. Furthermore, the prevention of cardio-specific enzyme leakage was achieved.

Moreover, *I. racemosa* effectively inhibited ischemic reperfusion-induced lipid peroxidation. These findings

suggest that the cardioprotective effects of *I. racemosa* are likely attributed to the improvement of antioxidant status, enhancement of hemodynamic parameters, and improvement in left ventricular contractile function, all of which contribute to the suppression of oxidativestress[40].

This study examined the potential cardioprotective effects of the compound Alantolactone (AL), which is derived from the roots of *I. racemosa*, against hypoxic/ischemic (H/I) injury caused by cobalt chloride ($CoCl_2$) *in vitro* and *in vivo* method myocardial infarction induced by isoproterenol. Clarifying AL's cardioprotective mechanism against these types of damage was the goal[41].

To evaluate heart function, tests measuring levels of cardiac troponin I (cTnI), and Lactate Dehydrogenase (LDH) were used as methodologies. The cardiac tissue was also subjected to histological examination[40].

In vitro studies using the patch-clamp method were used to see how AL affected isolated rat myocytes' L-type calcium current. Furthermore, several characteristics were investigated, including intracellular calcium concentration, mitochondrial membrane potential, oxidative stress damage, cell viability, and apoptosis.

The findings showed that AL therapy decreased levels of LDH, CK, and cTnI in addition to mitigating the morphological and ECG changes linked to MI. Additionally, the pretreatment of AL increased the activity of antioxidant enzymes while reducing the generation of Reactive Oxygen Species (ROS). Significantly, AL reduced ICa-L in a concentration- and time-dependent way while preventing mitochondrial damage, apoptosis, and calcium overload.

After further investigation, it was shown that AL had a maximum inhibitory effect and an IC_{50} of 17.29 µmol/L. All things considered, the results imply that AL reduced MI-related harm using apoptosis, oxidative stress, calcium excess, and mitochondrial damage. Interestingly, direct suppression of ICa-L by AL may be the cause of its cardioprotective effects[42].

5.12 Antiatherosclerosis Activity

Inula racemosa extracts effects on atherosclerosis in guinea pigs caused by a high-fat diet were examined in this research using alcohol and hexane extracts. Initially, six mice were assessed for early atherosclerotic alterations in the aorta, coronary arteries, and major organs after 30 days of a high-fat diet. After that, the animals that remained were divided into five groups and given various feeding regimens for ninety days, which included atorvastatin calcium, immune-related adverse event (IrA), Immune-related hepatitis IrHor positive controls. A pellet diet was the sole thing given to a normal control group. Many criteria, including blood cholesterol levels, and the state of antioxidants in the heart and liver, at the end evaluated location of aortic lesions and the histology of coronary arteries[43,44]. In contrast to the positive control, IrA showed significant increases in high-density lipoprotein cholesterol and decreases in total and low-density cholesterol[45]. IrA also enhanced cardiac glutathione peroxidase and superoxide dismutase, and scavenged reactive compounds related to thiobarbituric acid. It also raised liver-reduced glutathione levels. Bodyweight rise and aortic lesion area were least in the IrA-treated group. Additionally, the extracts corrected the alterations to the coronary arteries caused by the high-fat diet. For IrA, phenolics, and for IrH, sesquiterpene lactones, these actions are thought to be mediated. In summary, the findings of this research demonstrate *I. racemosa's* anti-atherogenic properties, hence, bolstering its conventional *Ayurvedic* uses for cardioprotection and anti-obesity[46].

5.13 Antihyper Cholesterolemic Activity

In a study involving 200 patients with ischemic heart disease, a combination therapy comprising guggul (*Commiphora mukul*) and Pushkarmool (*I. racemosa*) demonstrated significant efficacy in alleviating chest pain and improving functional status. Before treatment, patients experienced various grades of precordial pain and dyspnea, which were evaluated and assigned grades. Both dyspnea and precordial discomfort showed significant improvements after receiving the combination medication, and the Electrocardiogram (ECG) returned to normal. Significant reductions in total lipid, triglyceride, and cholesterol levels were also seen after therapy, suggesting that the combination medication regimen had a positive impact on lipid metabolism. Mechanisms of guggul were also examined in this research, and it was suggested that these features helped to lower the risk of cardiac events related to anti-ischemic medication. Furthermore, Pushkarmool's prostaglandin E2 (PGE2)-like boosting capacity and

post-exercise ECG restoration were considered to be contributing factors to the reported therapeutic benefits.

Overall, the study provides scientific evidence supporting the efficacy of the combined therapy of *guggul* and *Pushkarmool* in managing ischemic heart disease, with improvements in symptoms, lipid profiles, and cardiac function parameters. These findings underscore the potential of herbal combination therapies in the management of cardiovascular conditions[38].

5.14 Antiobesity and Antidyslipidemia Activity

Cardiovascular Disease (CVD) poses a significant global health challenge, affecting approximately 230 million individuals worldwide. This encompasses various heart and blood vessel ailments, including hypertension and chronic venous insufficiency, which can precipitate life-threatening events such as heart attacks and strokes. The interconnectedness of the cardiovascular system implies that damage or injury to one part can have cascading effects on others. Metabolic Syndrome (MS), characterized by hyperglycemia, dyslipidemia, and obesity, has reached epidemic proportions globally. There is an urgent need for a comprehensive understanding and management of MS, including affordable and effective strategies[38]. The comprehensive science of life known as *Ayurveda* provides insightful knowledge in this area. As an adjunct to a balanced diet and consistent exercise, *Ayurvedic* medicines, including guggul resin, *I. racemosa*, and arjuna, have been shown to enhance metabolic health. These herbs are thought to help prevent atherosclerosis, lower blood pressure, improve capillary integrity, inhibit destructive enzyme activity, and lower LDL cholesterol and triglyceride levels. One study looked specifically at the cardio-protective and hypoglycaemic effects of an extract made from the roots of *I. racemosa* in patients with confirmed MS cases. The evaluation revealed promising results, with the root extract of *I. racemosa* demonstrating effectiveness in correcting dyslipidemia and normalizing Body Mass Index (BMI). These findings underscore the potential of *Ayurvedic* interventions, particularly *I. racemosa*, in addressing the multifaceted challenges posed by metabolic syndrome and its associated cardiovascular risks[47].

5.15 Antidiabetic Activity

Inula racemosa (root) and *Gymnema sylvestre* (leaf) extracts were evaluated for their ability to alleviate corticosteroid-induced hyperglycemia in a mouse model, both alone and in combination. Additionally, the study sought to investigate whether the observed effects were mediated via alterations in thyroid hormone levels. Blood glucose levels significantly increased when the corticosteroid dexamethasone was administered, but triiodothyronine concentrations and serum thyroxine decreased concurrently, indicative of corticosteroid-induced hyperglycemia and perturbed thyroid function, respectively. Subsequent administration of either *I. racemosa* or *G. sylvestre* extracts, either alone or in combination, led to a notable reduction in serum glucose levels in dexamethasone-induced hyperglycaemic mice. However, the combined administration of both extracts exhibited superior efficacy in reducing hyperglycemia compared to individual extracts, mirroring the effects of the standard corticosteroid-inhibiting drug ketoconazole. Remarkably, the mice treated with dexamethasone showed no discernible alterations in thyroid hormone levels when they were given the plant extracts[48]. This suggests that the ameliorative effects of *I. racemosa* and *G. sylvestre* extracts on corticosteroid-induced hyperglycemia may not be mediated via modulation of thyroid hormone levels. The results show that extracts from both *I. racemosa* and *G. sylvestre* when combined, might be a promising treatment for hyperglycemia caused by steroids. Still, further study is needed to determine how these botanical extracts work and if they are safe and effective for treating hyperglycaemic disorders brought on by corticosteroid treatment[49].

After being given orally, *I. racemosa* root petroleum ether extract quickly reduced glucose and insulin levels in albino rats while also effectively counteracting adrenaline-induced hyperglycemia in rats. Additionally, the alcoholic extract of the roots exhibited hypoglycaemic effects and increased liver glycogen content, albeit without inducing insulin secretion from the pancreas. After three months of treatment with *I. racemosa* root powder, fifteen diabetic patients had statistically significant improvements in their blood glucose levels, according to clinical examinations. Research on mouse models of corticosteroid-induced hyperglycemia revealed that *I. racemosa* root extracts reduced blood concentrations of thyroid hormones, indicating a potential mediation role

for cortisol-inhibiting potency in the hypoglycaemic effects. Furthermore, both methanol and aqueous extracts lowered blood sugar levels in alloxan-induced hyperglycemia[50]. These findings collectively suggest the potential of *I. racemosa* root extracts as effective agents in managing hyperglycemia through various mechanisms, including cortisol inhibition, glycogen modulation, and direct glucose-lowering effects. To further understand how these extracts work and if they are useful for diabetic treatment, more studies are needed[51].

5.16 Antinephrotoxicity

The purpose of this research was to examine the harmful effects of acetaminophen on the kidneys and to determine whether or not aqueous extracts of *Capsella bursa-pastoris* and *I. racemosa* might alleviate these effects. The antioxidant properties of these extracts were investigated to counteract the oxidative stress induced by APAP overdose. Gas Chromatography-Mass Spectrometry (GC-MS) was used to examine the phytochemicals present in the extracts and to determine their stability at various pH levels. Male Swiss albino mice were randomly assigned to one of five groups for the *in vivo* analysis: control, APAP alone, APAP pretreated with *I. racemosa* (IR), APAP pretreated with *Capsella bursa-pastoris* (CBP), and APAP pretreated with UD. Both biochemical and histological tests showed that APAP overdose significantly altered nephrological architecture, body weight, and total protein concentration. However, pre-treatment with UD, CBP, or IR provided considerable nephroprotection, with the most pronounced effects observed in the UD group, followed by CBP and IR. These findings suggest that the herbal extracts have nephroprotective potential against APAP-induced nephropathy, although further investigation is required to elucidate the underlying mechanisms of action[52].

5.17 Antioxidant Activity

An uneven generation of reactive oxygen species within the body can lead to heightened oxidative stress, resulting in cellular and tissue damage that is associated with the development or worsening of several long-term health problems, such as inflammation, diabetes, cancer, heart disease, and obesity. It has recently come to light that secondary metabolites produced by *I. racemosa* species may be useful in the management of oxidative stress-related diseases.

To investigate this possibility, a thorough evaluation was carried out using different databases. Combining *I. racemosa*, antioxidant, and secondary metabolite-related phrases was the search method[53]. Over 120 articles were scrutinized, focusing on identifying the most active compounds and elucidating their mechanisms of antioxidative stress action. The goal of this effort was to learn more about their possible medicinal uses in the fight against diabetes, neurodegeneration, cancer, and inflammation. Because of its diverse bioactivities and impressive EC_{50} values across many tests, alantolactone stood out among the chemicals we looked at. Also, 1-O-acetylbritannilactone was a standout lead compound since it could be used to make analogues with good qualities. The research highlights the *I. racemosa* species as an abundant source of compounds with antioxidant action and various structural types. These compounds can fight human illnesses caused by oxidative stress via several mechanisms. Such insights not only contribute to expanding knowledge but also hold promise for the development of novel pharmaceutical interventions[54].

6. Conclusion

Inula racemosa, or *Pushkarmool*, has emerged as a versatile medicinal plant with a wide range of pharmacological activities. Its traditional use in *Ayurvedic* medicine finds support in contemporary scientific studies, which underscore its effectiveness in addressing various health issues. From combating inflammation and asthma to safeguarding the heart and liver, this plant exhibits a remarkable spectrum of therapeutic effects. Additionally, its antioxidant and antibacterial properties contribute to its overall medicinal value. The collective evidence from pharmacological investigations underscores the potential of *I. racemosa* as a valuable natural remedy, signalling the need for further research and clinical validation to fully harness its health benefits.

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