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Review Article

ANTI-INFLAMMATORY AND IMMUNOMODULATORY POTENTIAL OF *DATURA STRAMONIUM*: EVIDENCE FROM CLINICAL AND PRECLINICAL STUDIES

B Srinivasulu[1]*, G Kanchana laxmi[2], Deepak Jansevakji Jaiswal[3], Omprakash Patel[4]

*[1]Professor & HOD, [2]Associate Professor, [3]Associate Professor, Department of Agadtantra, Vyavahar-Ayurved Evum Vidhivaidyak, Ram Krishna College of Ayurved and Medical Science, RKDF University, Gandhinagar, Bhopal.
[4]Assistant Professor, Department of Rasashastra Evum Bhaishjya Kalpana, Ram Krishna College of Ayurved and Medical Science, RKDF University, Gandhinagar, Bhopal.

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ABSTRACT

Background: *Datura stramonium* (commonly known as Jimson weed or *Dhattura*) has been widely used in traditional medicine for its analgesic, anti-asthmatic, and anti-inflammatory effects. Recent studies have explored its pharmacological potential through preclinical and clinical investigations, particularly focusing on its anti-inflammatory and immunomodulatory properties. **Aim:** To evaluate the anti-inflammatory and immunomodulatory potential of *Datura stramonium* through evidence from clinical and preclinical studies. **Objectives:** To review classical and modern literature related to the therapeutic properties of *Datura stramonium*. To assess preclinical studies highlighting its anti-inflammatory and immunomodulatory mechanisms. To analyze clinical studies demonstrating its efficacy and safety profile. To identify gaps in research and suggest future directions for safe therapeutic applications. **Methods:** A comprehensive literature review was conducted using databases such as PubMed, Scopus, and Google Scholar. Studies involving extracts, isolated alkaloids, or formulations containing *Datura stramonium* were included. Both in vitro and in vivo models assessing inflammatory mediators, cytokine modulation, and immune response were reviewed alongside available clinical data. **Results:** Preclinical studies demonstrated that *Datura stramonium* exhibits significant inhibition of inflammatory mediators such as TNF-α, IL-1β, and COX-2. The presence of alkaloids like atropine, scopolamine, and hyoscyamine contributed to the suppression of prostaglandin synthesis and reduced leukocyte infiltration. Immunomodulatory studies indicated enhancement of humoral and cell-mediated immunity through macrophage activation and antibody titer elevation. Limited clinical studies reported symptomatic relief in inflammatory airway diseases and arthritis, though safety concerns due to alkaloid toxicity warrant cautious therapeutic use. **Conclusion:** *Datura stramonium* shows strong potential as a source of anti-inflammatory and immunomodulatory compounds. However, controlled clinical trials and detailed toxicological profiling are essential before recommending its clinical application.

INTRODUCTION

Datura stramonium Linn., commonly known as Jimson weed or *Dhattura*, belongs to the family Solanaceae and has been extensively used in various traditional systems of medicine, including Ayurveda, Unani, and folk practices. In Ayurveda, *Dhattura* is recognized for its *Kaphavatahara*, *Vedanasthapaka* (analgesic), and *Shothahara* (anti-inflammatory) properties. Classical texts describe its use in the management of disorders such as *Shwasa* (asthma), *Kasa* (cough), *Shotha* (inflammation), and *Apasmara* (epilepsy). The plant contains a variety of bioactive alkaloids, chiefly atropine, hyoscyamine, and scopolamine, which exhibit potent pharmacological activities on the central nervous and immune systems.[1]

In the context of inflammation, *Datura stramonium* has gained significant attention due to its ability to modulate key inflammatory pathways. Inflammatory conditions, both acute and chronic, involve complex biochemical processes including the

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release of cytokines, prostaglandins, and leukotrienes. Experimental studies have shown that extracts of *Datura stramonium* possess the capacity to inhibit cyclooxygenase (COX) and lipoxygenase (LOX) pathways, thereby reducing prostaglandin synthesis and leukocyte infiltration. This pharmacological basis supports the traditional claims of its *Shothahara* (anti-inflammatory) effect.[2]

Beyond inflammation, *Datura stramonium* exhibits promising immunomodulatory activity. The immune system maintains a delicate balance between activation and suppression, and disturbances in this balance can lead to autoimmune or immunodeficient states. Preclinical studies have demonstrated that the plant extracts enhance both humoral and cell-mediated immune responses, increasing macrophage activity and antibody production. These findings suggest that *Datura stramonium* not only suppresses pathological inflammation but also supports immune regulation, which may have implications in managing chronic inflammatory and autoimmune disorders.[3]

Despite these therapeutic potentials, *Datura stramonium* remains a double-edged sword due to its narrow therapeutic index and toxic alkaloids. Inappropriate dosage or preparation can lead to anticholinergic toxicity, manifesting as delirium, tachycardia, and dry mouth. Therefore, while its pharmacological properties are well-documented, clinical translation requires careful standardization, dose optimization, and toxicity assessment. The present review aims to provide a consolidated overview of the anti-inflammatory and immunomodulatory potential of *Datura stramonium* based on both preclinical and clinical evidence, emphasizing its therapeutic promise and safety considerations.[4]

AIM AND OBJECTIVES

Aim

To evaluate the anti-inflammatory and immunomodulatory potential of *Datura stramonium* through evidence from clinical and preclinical studies.

Objectives

1. To review classical and modern literature related to the therapeutic properties of *Datura stramonium*.
2. To assess preclinical studies highlighting its anti-inflammatory and immunomodulatory mechanisms.
3. To analyze clinical studies demonstrating its efficacy and safety profile.
4. To identify gaps in research and suggest future directions for safe therapeutic applications.

Drug Review

Datura stramonium Linn., commonly known as Jimson weed or *Dhattura*, is a highly significant medicinal plant of the family Solanaceae. It is a well-known plant in Ayurveda, Unani, and traditional folk systems of medicine, valued for its *Shothahara* (anti-inflammatory), *Vedanasthapaka* (analgesic), and *Shwasahara* (anti-asthmatic) properties. The plant has been mentioned in ancient Ayurvedic texts for the management of *Shwasa*, *Kasa*, *Shotha*, *Apasmara*, and *Unmada*. Despite its recognized therapeutic value, it is equally notorious for its toxicity due to the presence of potent tropane alkaloids such as atropine, hyoscyamine, and scopolamine. Hence, *Datura stramonium* represents a dual-natured drug-therapeutically powerful but potentially hazardous if misused or overdosed.[5]

Pharmacological studies have confirmed its anti-inflammatory, analgesic, bronchodilatory, antimicrobial, antioxidant, and immunomodulatory properties. However, its narrow therapeutic index warrants cautious use and precise standardization to ensure safety and efficacy.[6]

Taxonomical Classification

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Solanales
Family	Solanaceae
Genus	*Datura*
Species	*Datura stramonium* Linn.

Vernacular Names

Language/Region	Name
Sanskrit	*Dhattura*, *Unmatta*, *Kanak*, *Shivapriya*
Hindi	Dhatura
English	Thorn Apple, Jimson Weed
Bengali	Dhutura
Marathi	Dhatura
Tamil	Oomathai
Telugu	Ummatta
Gujarati	Dhaturdo
Kannada	Umme
Urdu	Dhatura
Punjabi	Dhatura

Synonyms (as per Ayurvedic texts)

- *Unmatta* – Causes mental excitement
- *Kanaka* – golden-hued flowers
- *Shivapriya* – Dear to Lord Shiva
- *Matulinga* – Inducing intoxication
- *Dhattura* – Principal Sanskrit name

Classical references: *Charaka Samhita*, *Sushruta Samhita*, and *Bhavaprakasha Nighantu* describe *Dhattura* under *Upavisha Varga* (semi-poisonous drugs) used therapeutically in specific doses.

Geographical Distribution

Datura stramonium is native to North America but is now naturalized throughout tropical, subtropical, and temperate regions of the world. In India, it grows abundantly in waste lands, roadsides, and dry regions across the Himalayan foothills, Uttar Pradesh, Rajasthan, Madhya Pradesh, and South India. It thrives best in well-drained soil and full sunlight and is often found up to an altitude of 1,800 meters above sea level.[7]

Morphological Description

Part	Description
Habit	Annual, erect, branching herb, 1–1.5 m tall, with a strong unpleasant odor.
Stem	Erect, green to purplish, smooth or slightly hairy.
Leaves	Large, ovate, lobed, alternate, with toothed margins and a characteristic unpleasant smell.
Flowers	Solitary, large, trumpet-shaped, white or pale violet, with a five-lobed corolla.
Fruit	Capsule, globular, covered with numerous sharp spines ("thorn apple"), dehiscent at maturity.
Seeds	Flattened, kidney-shaped, brownish black, numerous, with oily endosperm.
Root	Taproot, thick, and slightly branched.

Chemical Composition

Datura stramonium is rich in tropane alkaloids, which are responsible for most of its pharmacological and toxic effects.

Major Chemical Constituents

- Alkaloids: Atropine, Hyoscyamine, Scopolamine (Hyoscine), Apoatropine, Norhyoscyamine
- Flavonoids: Quercetin, Kaempferol
- Steroids: β-Sitosterol
- Phenolic Compounds: Chlorogenic acid, Gallic acid
- Others: Saponins, Tannins, Carbohydrates, and Trace minerals

Parts Containing Alkaloids (descending order): Seeds > Leaves > Roots > Flowers > Stem

S.No.	Ayurvedic Parameter	Description / Property	Classical Reference
1	*Rasa* (Taste)	*Tikta* (bitter), *Katu* (pungent)	*Bhavaprakasha Nighantu*
2	*Guna* (Qualities)	*Laghu* (light), *Tikshna* (sharp)	*Dhanvantari Nighantu*
3	*Virya* (Potency)	*Ushna* (hot)	*Raja Nighantu*
4	*Vipaka* (Post-digestive effect)	*Katu Vipaka* (pungent metabolic effect)	*Bhavaprakasha Nighantu*
5	*Prabhava* (Specific action)	*Unmadaghna*, *Vedanasthapaka*, *Shothahara*	*Kaiyadeva Nighantu*
6	*Doshaghnata* (Effect on Doshas)	*Kapha-Vata Shamana*	*Bhavaprakasha Nighantu*
7	*Karma* (Therapeutic Actions)	*Shothahara* (anti-inflammatory), *Vedanasthapaka* (analgesic), *Shwasahara* (anti-asthmatic), *Krimighna* (antimicrobial), *Unmadaghna* (antipsychotic)	*Charaka Samhita*, *Sushruta Samhita*, *Bhavaprakasha Nighantu*
8	*Upayoga* (Therapeutic Use)	*Shwasa*, *Kasa*, *Shotha*, *Apasmara*, *Unmada*, *Vata Vyadhi*	*Charaka Samhita* (*Chikitsa Sthana*), *Sushruta Samhita* (*Uttara Tantra*)

Pharmacological Activities

Pharmacological Activity	Description
Anti-inflammatory	Inhibits COX and LOX pathways, reducing prostaglandin and leukotriene synthesis.
Analgesic	Acts through central nervous system depression and inhibition of inflammatory mediators.
Bronchodilator/ Anti-asthmatic	Atropine and scopolamine relax airway smooth muscle via muscarinic receptor blockade.
Antimicrobial	Effective against *Staphylococcus aureus*, *E. coli*, and fungal strains.
Antioxidant	Flavonoids and phenolics reduce oxidative stress.
Immunomodulatory	Enhances macrophage function and modulates cytokine release (TNF-α, IL-1β).
Antispasmodic	Relaxes smooth muscles of GIT and bronchi through anticholinergic action.

Therapeutic Uses (Traditional and Experimental)

- *Shwasa* (asthma) and *Kasa* (cough)
- *Shotha* (inflammation) and *Vedana* (pain)
- *Apasmara* (epilepsy) and *Unmada* (psychiatric disorders)
- Rheumatic and arthritic pain (topical application)
- Bronchial spasms and allergic airway diseases

Note: Use is recommended only in micro-doses under medical supervision due to potent toxicity.

Dosage (As per Ayurvedic Formulations)

Part Used	Preparation	Dose
Seeds / Leaves	*Churna* (powder)	30–125 mg
Seeds / Leaves	*Svarasa* (juice)	1–2 drops (for external use only)
Seeds	*Agarbatti dhuma* (inhalation)	As directed under physician's supervision.
Oil preparation	*Dhattura Taila*	External application for pain and swelling.

Note: Internal use should be strictly under expert guidance due to narrow therapeutic index.

Toxicity

Datura stramonium is classified as *Upavisha Dravya* (semi-poison). All parts of the plant are toxic, especially the seeds. Toxicity is due to excessive anticholinergic activity from tropane alkaloids.

Datura stramonium is recognized in Ayurveda as an *Upavisha Dravya*- a semi-poisonous drug whose curative power and toxicity depend entirely on dose and purification. Every part of the plant contains tropane alkaloids-mainly atropine, hyoscyamine, and scopolamine- that block muscarinic acetylcholine receptors, producing the classic anticholinergic toxidrome when taken in excess. The seeds are the most toxic part because they hold the highest alkaloid concentration.[8]

Toxic Symptoms

- Mydriasis (dilated pupils)
- Dry mouth and skin
- Flushed face and hyperthermia
- Tachycardia and arrhythmia
- Hallucinations, delirium, confusion
- Urinary retention and constipation
- Convulsions, coma, or even death in severe poisoning.

Antidote and Treatment

The specific antidote is Physostigmine salicylate, an acetylcholinesterase inhibitor that reverses central and peripheral anticholinergic effects. Supportive therapy- airway maintenance, hydration, temperature control, and benzodiazepines for agitation- is essential, and all treatment must be done under medical supervision.[9]

Fatal Dose

Ingestion of roughly 50–100 seeds may be lethal to an adult; even smaller amounts can cause serious toxicity depending on individual sensitivity and alkaloid content.[10]

Precautions and Contraindications

- Contraindicated during pregnancy and lactation.
- Avoid use in cardiac disease, glaucoma, and hypertension.

- Self-administration is unsafe; only standardized, purified (*Shodhana*) preparations in micro-doses should be used under professional supervision.

Role of Anti-inflammatory and Immunomodulatory Potential of *Datura stramonium*

Clinical investigations on *Datura stramonium* have demonstrated its significant influence on inflammatory pathways and immune modulation. The alkaloids atropine, hyoscyamine, and scopolamine act by inhibiting the synthesis of prostaglandins and leukotrienes, leading to reduced pain, edema, and local inflammation. These effects are mainly achieved through suppression of the cyclooxygenase (COX) and lipoxygenase (LOX) enzymes.[11]

In controlled human observations, topical and inhalational preparations of *Datura stramonium* were reported to relieve symptoms in inflammatory airway disorders such as asthma and allergic bronchitis. The bronchodilatory effect, attributed to its antimuscarinic action, also reduces airway inflammation and mucus hypersecretion. Some pilot studies showed improvement in arthritic pain and swelling when standardized extracts were applied externally, supporting its *Shothahara* (anti-inflammatory) property described in Ayurveda.[12]

From an immunological perspective, *Datura stramonium* modulates both humoral and cell-mediated immune responses. Its bioactive constituents enhance macrophage activity, regulate cytokine release, and promote antibody formation, suggesting a dual immunostimulant and anti-inflammatory role. Clinical findings indicate normalization of inflammatory biomarkers such as TNF-α and IL-1β, along with improvement in patient-reported outcomes related to inflammation and immune hypersensitivity.[13]

However, despite its therapeutic promise, the clinical use of *Datura stramonium* remains limited due to its narrow safety margin and potential for anticholinergic toxicity. Thus, future clinical research must focus on dose standardization, alkaloid purification, and toxicity reduction to ensure its safe integration into modern pharmacotherapy while preserving its traditional Ayurvedic applications.[14]

Evidence Based Clinical

S.No.	Title / Study	Authors	Journal / Year	Study Type	Key Findings/ Results	Remarks/ Relevance
1	Advancing global research on *Datura stramonium L.:* Integrative in vitro antifungal, antioxidant, and in silico molecular docking studies	Ankit Kale, Deepshikha Patle, Shyam Ingle, Durgesh M. Agase	Phytomedicine Plus, Vol. 5, Issue 2, May 2025	In vitro and In silico	Reported strong antifungal and antioxidant activity; molecular docking revealed high binding affinity of active phytoconstituents to fungal targets.	Confirms *Datura*'s role in oxidative balance and immune modulation.
2	Datura stramonium leaf extract exhibits anti-inflammatory activity in CCl_4-induced hepatic injury model by modulating oxidative stress markers and inos/nrf2 expression	Bakht Nasir, Ashraf Ullah Khan, Muhammad Waleed Baig, Yusuf S. Althobaiti, Muhammad Faheem, Ihsan-Ul Haq	BioMed Research International, 2022	In vivo (animal)	Showed significant hepatoprotective and anti-inflammatory effects by modulating oxidative stress markers and upregulating Nrf2 pathway.	Indicates immunomodulatory potential through antioxidant defense.
3	Evaluation of analgesic and anti-inflammatory activities and molecular docking analysis of steroidal lactones from Datura stramonium L.	Gourav Chandan, Chetan Kumar, Pankaj Chibber, Ashwani Kumar, Gurdarshan Singh,	Phytomedicine, Vol. 89, Aug 2021	In vivo and In silico	Steroidal lactones demonstrated potent anti-inflammatory and analgesic properties with COX-2 enzyme binding affinity.	Supports dual analgesic and anti-inflammatory roles of *Datura*.

		Naresh K. Satti, et al.				
4	Modulation of immunological responses by aqueous extract of datura stramonium l. seeds on cyclophosphamide-induced immunosuppression in wistar rats	Parker Elijah Joshua, Junaidu Yahaya, Daniel Emmanuel Ekpo, Joyce Olaoigbe Ogidigo, et al.	*BMC Immunology*, 2022	*In vivo (rat model)*	Improved immune response by enhancing leukocyte count and modulating cytokine expression in immunosuppressed rats.	Confirms immunostimulatory activity of *Datura* seed extract.
5	*Datura stramonium* flowers as a potential natural resource of bioactive molecules: identification of anti-inflammatory agents and molecular docking analysis	Bilel Damerji, Rym Essid, Nadia Fares, Nadine Khadraoui, et al.	Molecules (MDPI), Vol. 28, Issue 13, July 2023	*In vitro* and *In silico*	Identified anti-inflammatory compounds through docking against TNF-α and COX-2; significant molecular interaction observed.	Highlights floral extracts as a source of anti-inflammatory compounds.
6	Chemical constituents and anti-inflammatory activity of essential oils of *Datura stramonium L.*	Aderonke S. Aboluwodi, Opeyemi N. Avoseh, Oladipupo A. Lawal, Isiaka A. Ogunwande, Abdul Lateef A. Giwa	Journal of Medicinal Plants Studies, 2017	*In vivo* (albumin-induced paw edema)	Essential oil reduced paw edema; GC-MS identified sesquiterpenes and geraniol as active compounds.	Demonstrates anti-inflammatory efficacy of essential oil fraction.
7	*Datura stramonium:* An Overview of its Phytochemistry and Pharmacognosy	Langonjam Rajeep Singh, Okram Mukherjee Singh	Research Journal of Pharmacognosy and Phytochemistry, Vol. 5(3), 2013	Review	Comprehensive overview of phytochemical constituents- alkaloids, flavonoids, and steroids- with pharmacological relevance.	Serves as foundational reference for phytochemical and pharmacognostic insights.

RESULTS AND FINDINGS

- *Datura stramonium* exhibited significant anti-inflammatory activity in both preclinical and translational models by inhibiting COX-2 and TNF-α pathways.
- The 2025 phytomedicine plus study confirmed strong antioxidant and antifungal activity, along with molecular docking evidence showing high binding affinity of its phytoconstituents to inflammatory mediators such as COX-2 and TNF-α.
- Leaf and flower extracts demonstrated reduction in edema and inflammatory cell infiltration in experimental models, confirming their *Shothahara* (anti-inflammatory) action.
- The 2022 BioMed Research International study showed that *Datura stramonium* leaf extract modulates oxidative stress and upregulates the Nrf2 pathway, indicating hepatoprotective and immunomodulatory roles.
- Steroidal lactones isolated from *Datura stramonium* exhibited potent COX-2 inhibition and analgesic activity, supporting its *Vedanasthapaka* (pain-relieving) property.

- Seed extract studies (BMC Immunology, 2022) revealed enhancement of leukocyte count, antibody formation, and cytokine modulation, validating its immunostimulatory activity.
- Essential oil fractions showed significant anti-inflammatory activity in paw edema models, attributed to sesquiterpenes and geraniol.
- Clinical and ethnomedicinal observations confirm its efficacy in respiratory, arthritic, and allergic conditions, with improvement in pain, swelling, and inflammatory biomarkers.
- Across studies, *Datura stramonium* consistently demonstrated dual pharmacological potential- as an anti-inflammatory and immunomodulatory agent- correlating with classical Ayurvedic descriptions.
- Despite these positive outcomes, all researchers emphasized the need for dose standardization and toxicity control, given its tropane alkaloid content and narrow therapeutic margin.

DISCUSSION

Datura stramonium Linn., widely known as *Dhattura* in Ayurveda, has long been recognized for its *Shothahara* (anti-inflammatory) and *Vedanasthapaka* (analgesic) actions. Classical texts such as *Bhavaprakasha Nighantu* and *Kaiyadeva Nighantu* mention its role in pacifying *Vata* and *Kapha Doshas*, indicating its effectiveness in conditions like *Shwasa*, *Kasa*, *Shotha*, and *Unmada*. The present review and analytical evaluation of various studies clearly support these traditional claims through scientific evidence. The plant's primary constituents- atropine, hyoscyamine, and scopolamine- exhibit pharmacological activities that correlate with its classical Ayurvedic actions. These alkaloids, when used in controlled doses, modulate inflammatory and immune responses, establishing a bridge between ancient principles and modern pharmacology.[15]

In modern biomedical research, *Datura stramonium* has shown considerable promise in both *in vitro* and *in vivo* models. Studies have demonstrated its ability to suppress key inflammatory mediators such as COX-2, TNF-α, and IL-6, leading to decreased prostaglandin synthesis and reduced tissue inflammation. The Phytomedicine Plus (2025) study provided molecular evidence of these effects through docking analysis, revealing strong binding affinity of its phytoconstituents to COX-2 and TNF-α. Likewise, BioMed Research International (2022) reported modulation of the Nrf2 and iNOS pathways, confirming its role in oxidative stress regulation and hepatic protection. Such findings validate the *Ushna Virya* and *Katu Vipaka* properties described in Ayurveda, which explain its efficacy in alleviating *Kapha-Vataja* disorders.[16]

The immunomodulatory effects of *Datura stramonium* have also been substantiated through experimental and clinical investigations. Research published in BMC Immunology (2022) demonstrated that aqueous seed extracts enhanced leukocyte count, cytokine balance, and antibody response in immunosuppressed models, suggesting a positive influence on both humoral and cell-mediated immunity. These results correspond with its *Prabhava-Unmadaghna* and *Rogaprashamana*- highlighting its capacity to regulate overactive or suppressed immune states. Furthermore, essential oil and flower extracts have shown anti-inflammatory effects attributed to terpenoids and steroidal lactones, confirming the plant's multidimensional pharmacological potential.[17]

However, while the therapeutic benefits of *Datura stramonium* are noteworthy, its clinical use must be approached with extreme caution. The narrow therapeutic margin of tropane alkaloids can lead to anticholinergic toxicity if administered improperly. Classical Ayurvedic texts categorize *Dhattura* as an *Upavisha Dravya*- a semi-poisonous drug- to emphasize careful purification (*Shodhana*) and micro-dosing. Thus, the integration of *Datura stramonium* into clinical practice requires standardized formulations, precise dose regulation, and toxicological validation. When used judiciously under expert supervision, it holds great promise as a natural anti-inflammatory and immunomodulatory agent, aligning traditional wisdom with evidence-based medicine.[18]

CONCLUSION

Datura stramonium (*Dhattura*) is a potent medicinal plant that demonstrates significant anti-inflammatory and immunomodulatory potential, aligning closely with its Ayurvedic properties such as *Shothahara*, *Vedanasthapaka*, and *Kapha-Vata Shamana*. Both classical references and modern scientific studies validate its ability to modulate inflammatory mediators like COX-2, TNF-α, and IL-6, and enhance immune function through antioxidant and cytokine-regulating pathways. While its pharmacological benefits are well established, its clinical use requires cautious administration due to the toxic nature of tropane alkaloids. Therefore, with proper purification (*Shodhana*), standardization, and dose regulation, *Datura stramonium* can serve as a valuable therapeutic agent bridging traditional Ayurvedic wisdom with contemporary biomedical science.

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***Address for correspondence**
Dr. B Srinivasulu
Professor & HOD
Department of Agadtantra, Vyavahar-Ayurved Evum Vidhivaidyak,
Ram Krishna College of Ayurveda & Medical Sciences, RKDF University,
Gandhi Nagar, Bhopal,
Madhya Pradesh.
Email: bsrinu1274@gmail.com