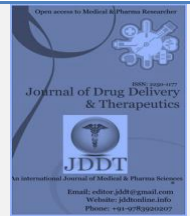


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Review Article

Medicinal Plants in the Management of Urolithiasis: Phytochemical Constituents and Pharmacological Evidence

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Abstract

Objective: To systematically review the role of medicinal plants in the management of urolithiasis, with a focus on their phytochemical constituents, pharmacological activities, and underlying mechanisms of action.

Data Sources: A comprehensive literature search was conducted using electronic databases including PubMed, Scopus, Google Scholar, and ScienceDirect for relevant studies published on medicinal plants and urolithiasis.

Study Selection: Relevant preclinical, clinical, and review studies published in English were selected based on their relevance to antiurolithiatic activity, phytochemistry, and mechanisms of action. Studies lacking scientific validation or insufficient data were excluded.

Summary of Content: Urolithiasis is a recurrent disorder characterized by the formation of urinary calculi due to supersaturation of lithogenic substances. Medicinal plants such as *Phyllanthus niruri*, *Tribulus terrestris*, and *Bergenia ligulata* have demonstrated significant anti-urolithiatic activity. These plants contain bioactive phytoconstituents including flavonoids, saponins, alkaloids, and phenolic compounds, which contribute to their therapeutic effects. The mechanisms involved include inhibition of crystal nucleation, growth and aggregation, antioxidant and anti-inflammatory actions, diuretic effects, and modulation of urinary biochemical parameters. Experimental and limited clinical studies have reported promising outcomes in reducing stone formation and promoting stone expulsion.

Conclusion: Medicinal plants offer a promising complementary approach for the management of urolithiasis. However, further well-designed clinical trials and standardization of herbal formulations are required to establish their safety, efficacy, and clinical applicability.

Keywords: Urolithiasis, medicinal plants, antiurolithiatic activity, phytochemistry, kidney stones

Introduction

Urolithiasis is a multifactorial disorder affecting approximately 10–12% of the global population, with a high rate of recurrence^{1,2}. It is characterized by the formation of calculi in the kidneys or urinary tract due to supersaturation of urine with stone-forming constituents³. Among various types, calcium oxalate stones are the most common, accounting for nearly 70–80% of cases⁴. Conventional management approaches, including extracorporeal shock wave lithotripsy, surgical interventions, and pharmacotherapy, provide symptomatic relief but often fail to prevent recurrence^{5,6}. This limitation has led to increased interest in medicinal plants, which have been traditionally used for the management of urolithiasis in systems such as Ayurveda and Unani medicine^{7,8}.

Objective

The objective of this review is to evaluate the role of medicinal plants in the management of urolithiasis with emphasis on their phytochemical constituents, pharmacological activities, and mechanisms of action.

Data Sources

Data for this review were collected from electronic databases including PubMed, Scopus, Google Scholar, and ScienceDirect.

Study Selection

Relevant preclinical, clinical, and review articles published in English were selected based on their relevance to antiurolithiatic activity, phytochemistry, and mechanisms of action.

Pathophysiology of Urolithiasis

Stone formation is a complex process involving urinary supersaturation, nucleation, crystal growth, aggregation, and retention within renal tubules⁹. Factors such as hyperoxaluria, hypercalciuria, hypocitraturia, and

reduced urine volume significantly contribute to lithogenesis^{10,11}. Oxidative stress plays a critical role in renal epithelial injury, promoting crystal adhesion and retention¹². Inflammatory mediators further exacerbate tissue damage, facilitating stone formation¹

PATHOPHYSIOLOGY OF UROLITHIASIS

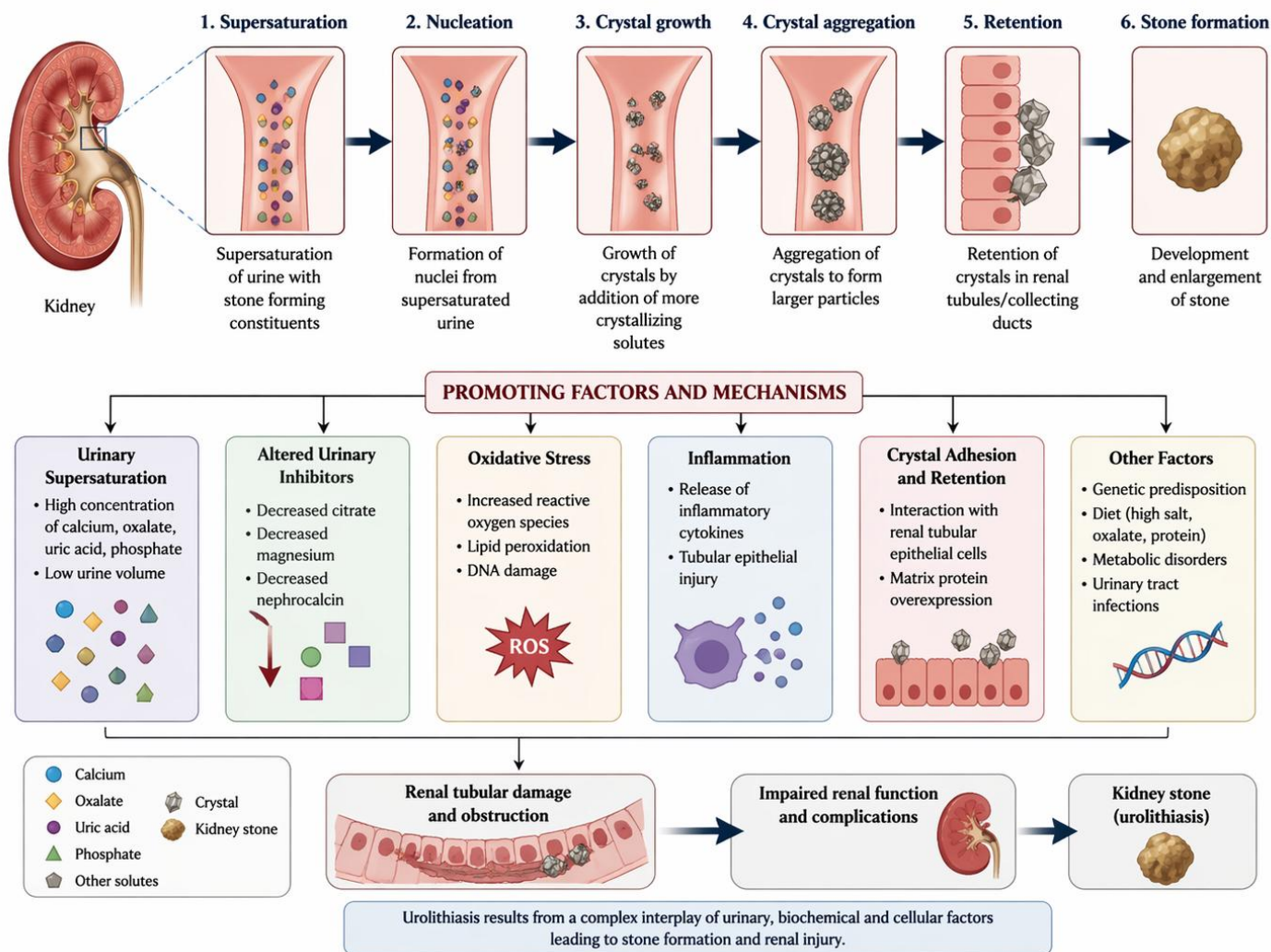


Figure 1.1 Diagrammatic representation of Pathophysiology of Urolithiasis

Traditional and Ethnobotanical Perspective

Urolithiasis has been extensively described in traditional Indian systems of medicine, particularly Ayurveda, where it is referred to as Ashmari^{73,74}. Classical texts such as Charaka Samhita and Sushruta Samhita document the use of plant-based formulations for the dissolution and expulsion of urinary calculi. Medicinal plants such as *Bergenia ligulata*, *Tribulus terrestris*, *Aerva lanata*, *Phyllanthus niruri*, and *Crataeva nurvala* have been widely used for their diuretic and litholytic properties⁷⁵⁻⁷⁷. In Unani medicine, herbal drugs with stone-dissolving and diuretic actions are commonly prescribed⁷⁸. Ethnobotanical studies also report the

continued use of herbal preparations for kidney stone management across various regions of India^{79,80}.

Phytochemistry of Antiurolithiatic Medicinal Plants

Medicinal plants exhibit antiurolithiatic effects due to the presence of diverse bioactive phytochemicals. Flavonoids and polyphenols possess strong antioxidant properties that protect renal epithelial cells from oxidative damage^{14,15}. Saponins inhibit crystal aggregation by altering surface tension and crystal morphology¹⁶. Alkaloids and terpenoids exhibit diuretic and anti-inflammatory effects, aiding in stone expulsion^{17,18}.

Tannins and phenolic compounds interfere with calcium oxalate crystallization and reduce renal injury¹⁹.

Mechanisms of Antiurolithiatic Action

Medicinal plants act through multiple mechanisms to prevent and treat urolithiasis. They inhibit crystal nucleation, growth, and aggregation, thereby preventing stone formation^{20,21}. Antioxidant activity reduces oxidative stress-induced renal damage^{22,23}. Diuretic effects increase urine output, decreasing supersaturation of lithogenic substances²⁴. Additionally, herbal agents modulate urinary biochemical parameters such as calcium, oxalate, phosphate, and citrate levels^{25,26}.

Important Medicinal Plants in Urolithiasis

Several medicinal plants have demonstrated significant antiurolithiatic activity. *Phyllanthus niruri* inhibits calcium oxalate crystal growth and promotes stone expulsion^{27,28}. *Aerva lanata* reduces urinary calcium and oxalate levels and prevents crystal deposition²⁹. *Tribulus terrestris* exhibits diuretic and anti-inflammatory properties³⁰. Other plants such as *Dolichos biflorus*, *Bergenia ligulata*, and *Hibiscus sabdariffa* have shown promising results in experimental models³¹⁻³³.

Table 1: Selected medicinal plants with reported anti-urolithiatic activity

S. No.	Medicinal plant	Family	Part used	Reported activity	Proposed mechanism	Ref.
1.	<i>Tribulus terrestris</i>	Zygophyllaceae	Fruits	Prevents CaOx stone formation	Inhibits crystal nucleation & aggregation	[51,52]
2.	<i>Bergenia ligulata</i>	Saxifragaceae	Rhizome	Lithotriptic activity	Calcium chelation, diuretic effect	[53,54]
3.	<i>Aerva lanata</i>	Amaranthaceae	Whole plant	Reduces stone recurrence	Diuretic, antioxidant	[55,56]
4.	<i>Crataeva nurvala</i>	Capparaceae	Bark	Anti-nephrolithiatic	Reduces urinary oxalate	[57,58]
5.	<i>Phyllanthus niruri</i>	Euphorbiaceae	Whole plant	Inhibits stone growth	Modulates crystallization	[59,60]
6.	<i>Hygrophila spinosa</i>	Acanthaceae	Seeds	Reduces renal calculi	Diuretic, anti-inflammatory	[61]
7.	<i>Rotula aquatica</i>	Boraginaceae	Roots	Litholytic activity	Dissolution of CaOx stones	[62,63]
8.	<i>Dolichos biflorus</i>	Fabaceae	Seeds	Prevents stone formation	Antioxidant, nephroprotective	[64]
9.	<i>Asparagus racemosus</i>	Asparagaceae	Roots	Anti-urolithiatic Diuretic	renal protection	[65]
10.	<i>Cynodon dactylon</i>	Poaceae	Whole plant	Reduces stone size	Inhibits aggregation	[66]
11.	<i>Boerhaavia diffusa</i>	Nyctaginaceae	Roots	Nephroprotective	Antioxidant, diuretic	[67,68]
12.	<i>Terminalia chebula</i>	Combretaceae	Fruits	Prevents nephrolithiasis	Free-radical scavenging	[69]
13.	<i>Moringa oleifera</i>	Moringaceae	Leaves	Anti-urolithiatic	Regulates urinary electrolytes	[70]
14.	<i>Cissus quadrangularis</i>	Vitaceae	Stem	Stone prevention	Inhibits crystal growth	[21]
15.	<i>Solanum nigrum</i>	Solanaceae	Whole plant	Reduces CaOx deposition	Anti-inflammatory, antioxidant	[72]

Experimental and Clinical Evidence

Experimental studies using ethylene glycol-induced urolithiasis models have demonstrated the protective effects of plant extracts against renal stone formation³⁴⁻³⁶. Clinical studies evaluating herbal formulations have reported reduction in stone size, improvement in urinary parameters, and increased stone expulsion rates with minimal adverse effects³⁷⁻⁴⁰. However, large-scale randomized controlled trials are still limited.

Limitations and Challenges of Herbal Therapies

Despite promising results, several challenges limit the widespread clinical application of medicinal plants. Variability in phytochemical composition due to geographical and environmental factors leads to inconsistent pharmacological outcomes⁸¹. Lack of standardized formulations and insufficient clinical trials further restrict their acceptance⁷⁷. Additionally, herb-drug interactions and limited safety data raise concerns regarding their concurrent use with conventional therapies⁸². Regulatory issues, lack of quality control, and absence of validated biomarkers further pose significant challenges⁸³.

Future Perspectives

Future research should focus on the isolation and characterization of active phytoconstituents responsible for antiurolithiatic activity. Advanced molecular and pharmacological approaches may help elucidate precise mechanisms involved in crystal inhibition and renal protection⁸⁴. Standardization of herbal formulations, along with dose optimization and toxicity evaluation, is essential to ensure safety and efficacy⁸⁵. Moreover, well-designed multicentric clinical trials are required to validate traditional claims and establish evidence-based therapies^{86, 87}.

Conclusions

Medicinal plants offer a promising complementary approach for the management of urolithiasis due to their multitarget mechanisms of action. Phytochemical-rich extracts inhibit stone formation, protect renal tissue, and improve urinary parameters. Integration of herbal therapies with conventional treatment may provide a safer and more effective strategy for long-term management of urolithiasis⁴⁶⁻⁵⁰.

Authors' Contribution: P. Bagdi designed the study, performed experiments, analysed data, and wrote the manuscript.

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Author Contribution (CRediT Statement): Dr. Pooja Bagdi: Conceptualization, Literature review, Data collection, Writing – original draft preparation, Writing – review and editing.

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