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Herbal Nephroprotective Agents in the Management of Kidney Disorders: An Integrative Scientific and Ayurvedic Review

Ashwini Jeerankalagi [1], Jyoti Ganer [1] and Shivanand Biradar [2]

[1] *Department of Agada Tantra Evum Vidhivaidyaka, Uttaranchal Medical College of Ayurveda and Research, Dehradun, Uttarakhand, India.*
[2] *Department of Rasa Shastra and Bhaishajya Kalpana, Sai Ayurveda College, Vairag, Dist: Solapur, Maharashtra, India.*

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Abstract

Kidney diseases, including chronic kidney disease (CKD), nephritis, cystitis, dysuria, and urolithiasis, constitute a major and expanding global health burden. Conventional therapies primarily aim to slow disease progression and manage complications but are frequently limited by adverse effects, nephrotoxicity, and high economic costs. Consequently, there is increasing scientific and clinical interest in herbal medicines as complementary strategies for renal protection and repair. This integrative review critically evaluates six medicinal plants—*Vetiveria zizanioides* (Ushira), *Anethum sowa* (Sowa), *Apium graveolens* (Ajmoda), *Amaranthus spinosus* (Tanduliya), *Cynodon dactylon* (Durva), and *Cyperus rotundus* (Musta)—that are widely used in Ayurvedic and ethno medicinal systems for renal and urinary tract disorders. These plants are rich in bioactive constituents, including sesquiterpenoids, flavonoids, phthalides, phenolic compounds, and beta-sitosterol, which exerts nephroprotective, effects through antioxidant, anti-inflammatory, diuretic, anti-fibrotic, and anti-crystallization mechanisms. Experimental studies demonstrate significant improvements in renal biochemical markers and histopathological architecture. Notably, nootkatone from *Vetiveria zizanioides* shows strong renoprotective and renal repair activity through modulation of NRF2 and NF-κB signaling pathways. Collectively, the evidence supports the potential role of these herbal drugs as multitarget, safe, and cost-effective adjuncts in the prevention and management of kidney disorders.

Keywords: Nephroprotection; Diuretics; Renal Disorders; Pharmacokinetics; Pharmacodynamics; Herbal drugs

1. Introduction

Chronic kidney disease (CKD) is a major public health problem worldwide and is associated with increased morbidity, mortality, and healthcare expenditure [1, 2]. Current therapeutic strategies, including diuretics, corticosteroids, and renal replacement therapies, are largely palliative and do not directly restore damaged renal tissue. In addition, prolonged exposure to nephrotoxic drugs such as non-steroidal anti-inflammatory drugs and certain chemotherapeutic agents further accelerates renal dysfunction and disease progression.

Traditional systems of medicine, including Ayurveda, Unani, and Siddha, have long employed plant-based therapies for the management of urinary and renal disorders. Recent experimental and mechanistic studies have provided pharmacological validation for these practices by demonstrating that phytochemicals can attenuate oxidative stress, suppress inflammatory signaling, inhibit fibrosis, and reduce crystal formation within renal tissues [3, 4]. In particular, activation of cytoprotective pathways such as nuclear factor erythroid 2-related factor 2 (NRF2) and down regulation of pro-inflammatory transcription factors such as nuclear factor-κB (NF-κB) are now recognized as central mechanisms underlying herbal nephroprotection.

*Corresponding author: Ashwini Jeerankalagi

This review integrates classical Ayurvedic concepts with contemporary experimental evidence to synthesize current knowledge on selected medicinal plants and their mechanistic roles in renal protection and repair.

2. Materials and Methods (Review Methodology)

A comprehensive literature search was conducted on Indian Medicinal Plants by C P Khare and also using PubMed, PubMed Central, MDPI, Wiley Online Library, and ScienceDirect databases. Search terms included combinations of: nephroprotection, renal oxidative stress, urolithiasis, *Vetiveria zizanioides*, *Cynodon dactylon*, *Cyperus rotundus*, *Apium graveolens*, *Amaranthus spinosus*, *Anethum sowa*, NRF2, and inflammatory signaling pathways.

Peer-reviewed articles published between 2021 and 2025 were preferentially included. Experimental in vivo, in vitro, and mechanistic studies reporting changes in renal function markers, oxidative stress indices, inflammatory mediators, and renal histopathology were analyzed and qualitatively synthesized.

3. Results

Table 1 Medicinal Plant, Parts Used, and Major Phytoconstituents

Common Name	Botanical Name	Part Used	Major Chemical Constituents
Ushira	*Vetiveria zizanioides*	Roots	Nootkatone, khusimol, vetiselinenol, sesquiterpenoids
Sowa	*Anethum sowa*	Leaves	Carvone, flavonoids, coumarins
Ajmodaa	*Apium graveolens*	Leaves/Seeds	Phthalides, apigenin, apiin, limonene
Tanduliya	*Amaranthus spinosus*	Whole plant/Roots	Phenolics, antioxidant compounds
Durva	*Cynodon dactylon*	Whole plant	Tricin, flavonoids, phenolic acids
Musta	*Cyperus rotundus*	Rhizome/Tuber	Beta-sitosterol, eudesmane sesquiterpenes

Table 2 Traditional Uses and Mode of Action in Kidney Disorders

Herb	Traditional Uses	Mode of Action
Vetiveria zizanioides	Dysuria, nephritis, urinary inflammation	Antioxidant, anti-inflammatory, antifibrotic
Anethum sowa	Urinary tract disorders	Diuretic, vasodilator, antioxidant
Apium graveolens	Urinary inflammation, hyperuricemia	Diuretic, Na^+/K^+-ATPase inhibition
Amaranthus spinosus	Diuretic, detoxification	Antioxidant, tubular protection
Cynodon dactylon	Cystitis, nephritis, dysuria	Anti-inflammatory, anti-crystallization
Cyperus rotundus	Dysuria, urolithiasis	Anti-crystallization, anti-inflammatory

Table 3 Recent Experimental Evidence Supporting Nephroprotection

Herb	Experimental Model	Key Findings	Reference
Vetiveria zizanioides	Doxorubicin-induced nephrotoxicity (rats)	↓ Creatinine, ↓ BUN, ↓ fibrosis, ↑ antioxidants	Amarasiri et al., 2021 [5]
Vetiveria zizanioides	CKD rat model	NRF2 activation, reduced inflammation	Phytomedicine, 2025 [6]

Apium graveolens	Hyperuricemia / cisplatin model	↓ Uric acid, improved histology	J Ethnopharmacol [7]
Cynodon dactylon	EG-induced urolithiasis	↓ CaOx deposition	Pharmacogn Rev [8]
Cyperus rotundus	CaOx nucleation assay	Inhibition of crystal aggregation	J Ethnopharmacol [9]
Amaranthus spinosus	CCl_4 nephrotoxicity	Restoration of antioxidants, histology	Pharmacogn Mag [10]

Table 4 Molecular Mechanisms of Herbal Nephroprotection

Mechanism	Biological Effect
NRF2 activation	↑ SOD, CAT, GSH, HO-1 (antioxidant defence)
NF-κB inhibition	↓ TNF-α, IL-6, IL-1β (anti-inflammatory)
Anti-crystallization	↓ CaOx nucleation and aggregation
Diuretic activity	↑ Clearance of nephrotoxins
Antifibrotic action	↓ TGF-β1, collagen deposition

4. Ayurvedic and Ethno medicinal Relevance in Renal Disorders

4.1. *Vetiveria zizanioides* (Ushira)

Ushira is described in *Charaka Samhita* and *Bhavaprakasha Nighantu* as *Mutrala* (diuretic), *Sheetala* (cooling), and *Pittahara*, and is indicated in *Mutrakrichra*, *Daha* (burning micturition), and inflammatory conditions of the urinary tract. It's cooling, anti-inflammatory, and soothing actions are traditionally employed to alleviate dysuria and irritation of the urinary passages.

Contemporary experimental studies demonstrate significant nephroprotective activity of *Vetiveria zizanioides*, attributed mainly to sesquiterpenes such as nootkatone. These constituents attenuate oxidative stress, inflammatory responses, and apoptotic pathways in toxin-induced nephrotoxicity models. Marked reductions in serum creatinine, blood urea nitrogen (BUN), and renal histopathological injury have been reported in doxorubicin- and melamine-induced renal damage models, supporting its traditional use.

4.2. *Apium graveolens* (Ajmodaa)

Ajmodaa is described in Ayurvedic and Unani systems as *Mutrala* and *Shothahara* and is traditionally prescribed for urinary tract inflammation, edema, and painful micturition. It is also recommended for relieving urinary obstruction and for balancing *Kapha* and *Vata* disorders affecting the urinary system.

Pharmacological evidence confirms that *Apium graveolens* exhibits diuretic, hypotensive, and anti-inflammatory effects mediated by phthalides and flavonoids. Experimental studies have demonstrated protection against cisplatin-induced nephrotoxicity, along with improvements in oxidative stress parameters and renal biomarkers, thereby supporting its traditional application in renal inflammation and toxin-mediated renal injury.

4.3. *Cynodon dactylon* (Durva)

Durva is classified in Ayurveda as *Mutrala*, *Kashaya* (astringent), and *Raktastambhaka*, and is indicated in *Mutrakrichra*, *Raktamutrata* (hematuria), cystitis, and inflammatory urinary disorders. Classical texts such as *Sushruta Samhita* describe its utility in controlling bleeding and reducing inflammation within the urinary tract.

Modern pharmacological studies demonstrate that *Cynodon dactylon* possesses flavonoid- and phenolic-mediated antioxidant and anti-inflammatory activities. Experimental models of urolithiasis and nephritis confirm its ability to reduce calcium oxalate crystal deposition, renal inflammation, and oxidative injury, thereby validating its traditional use in cystitis and nephritis.

4.4. *Cyperus rotundus* (Musta / Nagarmotha)

Musta is extensively described in *Charaka Samhita* and *Dhanvantari Nighantu* as *Deepana*, *Pachana*, *Mutrala*, and *Shothahara*. It is traditionally prescribed in urinary disorders associated with pain, inflammation, and obstructive conditions.

Scientific investigations confirm that *Cyperus rotundus* exhibits potent anti-inflammatory, antioxidant, and anti-urolithiatic activities. Bioactive constituents such as beta-sitosterol and sesquiterpenes inhibit edema, oxidative stress, and calcium oxalate nucleation and aggregation. Both in vitro and in vivo studies support its role in preventing renal stone formation and mitigating inflammatory renal injury.

4.5. *Amaranthus spinosus* (Tanduliya)

Tanduliya is traditionally described as *Mutrala*, *Shothahara*, and *Balya* in Ayurveda and is used in urinary inflammation, edema, and detoxification therapies. It is also incorporated into dietary and medicinal preparations for supporting renal and metabolic health.

Experimental evidence indicates that *Amaranthus spinosus* root and leaf extracts significantly restore antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH), normalize renal biochemical markers, and reverse histopathological damage in carbon tetrachloride-induced nephrotoxicity models. These findings support its nephroprotective and detoxifying roles described in traditional medicine.

4.6. *Anethum sowa* (Sowa / Indian Dill)

Sowa is traditionally indicated as *Mutrala*, *Shoolahara* (antispasmodic), and *Vatanulomana*. Classical formulations recommend its use in painful micturition, urinary spasms, and obstructive urinary conditions.

Pharmacological studies confirm that *Anethum sowa* exhibits vasodilatory, diuretic, and antispasmodic activities. Aqueous extracts have been shown to lower blood pressure, improve renal perfusion, and enhance urinary output, supporting its traditional use in dysuria and urinary tract spasms.

4.7. Summary

Table 5 Ayurvedic and Scientific Evidence in Renal Disorders

Herb	Ayurvedic Indications	Classical Actions	Scientific Evidence
Vetiveria zizanioides	Mutrakrichra, Daha	Mutrala, Sheetala	Antioxidant, nephroprotective, ↓ creatinine/BUN
Apium graveolens	Shotha, Mutravikara	Mutrala, Shothahara	Diuretic, cisplatin nephroprotection
Cynodon dactylon	Raktamutrata, Cystitis	Kashaya, Mutrala	Anti-urolithiatic, anti-inflammatory
Cyperus rotundus	Mutrakrichra, Shotha	Deepana, Mutrala	Anti-stone, antioxidant, anti-inflammatory
Amaranthus spinosus	Shotha, Detoxification	Mutrala, Balya	Antioxidant, histological renal repair
Anethum sowa	Mutrashoola	Mutrala, Shoolahara	Diuretic, antispasmodic

5. Discussion

The medicinal plants reviewed demonstrate broad-spectrum nephroprotective activity by targeting multiple pathological processes involved in kidney disease progression, including oxidative stress, inflammatory responses, fibrotic remodeling, and crystal deposition. Such multitarget actions contrast with conventional pharmacological agents, which often focus on single pathways and may be associated with drug-related renal toxicity.

Among the phytochemicals evaluated, nootkatone derived from *Vetiveria zizanioides* shows the most consistent and robust evidence for renoprotective and renal repair activity. Improvements in renal biochemical parameters, antioxidant enzyme status, and histological architecture across multiple experimental models suggest a strong

therapeutic potential. The ability of nootkatone to activate NRF2-mediated antioxidant defense while suppressing NF-κB-driven inflammatory signaling provides a well-defined molecular rationale for its protective effects.

Despite encouraging preclinical data, clinical translation remains limited by the lack of large-scale, well-controlled human trials. Standardization of extracts, pharmacokinetic characterization, dose optimization, and long-term safety evaluation are essential prerequisites for routine clinical integration.

6. Conclusion

Collective experimental and traditional evidence indicates that *Vetiveria zizanioides*, *Apium graveolens*, *Cynodon dactylon*, *Cyperus rotundus*, *Amaranthus spinosus*, and *Anethum sowa* possess significant nephroprotective properties mediated through antioxidant, anti-inflammatory, diuretic, and anti-crystallization mechanisms. Among these, nootkatone from *V. zizanioides* demonstrates the strongest experimental support for renal protection and repair through modulation of NRF2 and NF-κB signaling pathways. These herbal drugs represent promising complementary therapeutic candidates for the prevention and management of CKD and related renal disorders. However, rigorous clinical validation is required to confirm their efficacy and safety in human populations.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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