

Available online on 15.06.2026 at <http://ajprd.com>

Asian Journal of Pharmaceutical Research and Development

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Review Article

Pharmacochemical Insights of *Pedaliium Murex L.* With Emphasis on Recent Formulations, Phytochemistry and Biological Activities

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ABSTRACT

Pedaliium murex Linn. (Family: Zygophyllaceae), commonly known as Bada Gokhru in Hindi and Large Caltrops in English, is a remarkable annual herb widely distributed across arid and semi-arid regions of India, Sri Lanka, Pakistan, and parts of Africa. It has been esteemed in traditional systems of medicine Ayurveda, Unani, and Siddha chiefly for its diuretic, aphrodisiac, anti-urolithiatic, and tonic properties. The plant, particularly its spiny fruits, is rich in diverse phytochemicals including saponins, flavonoids (quercetin, luteolin), alkaloids, sterols (β -sitosterol), tannins, terpenoids (ursolic acid), mucilage, and fixed oils. Scientific validation of its traditional claims has intensified over the past two decades, revealing potent antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, analgesic, antidiabetic, hypolipidaemic, anticancer, and wound-healing activities. Recent pharmaceutical research has focused on development of novel drug delivery systems nanoparticles, phytosomes, liposomal gels, transdermal patches, and PLGA microspheres to overcome limitations of bioavailability and stability. This review comprehensively discusses the botanical, phytochemical, pharmacological, and formulation aspects of *Pedaliium murex*, with particular emphasis on advancements in the last decade.

Keywords: *Pedaliium murex*, Bada Gokhru, phytochemistry, anti-urolithiatic, novel drug delivery, pharmacological activity, Zygophyllaceae.

ARTICLE INFO: Received 08 Jan. 2026; Review Complete 28 April, 2026; Accepted 23 May . 2026; Available online 15 June. 2026



Cite this article as:

Kaur S, Isha*, Kaur M, Sharma S, Gill NS, Pharmacochemical Insights of *Pedaliium Murex L.* With Emphasis on Recent Formulations, Phytochemistry and Biological Activities, Asian Journal of Pharmaceutical Research and Development. 2026; 14(3):197-204, DOI: <http://dx.doi.org/10.22270/ajprd.v14i3.1780>

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INTRODUCTION

Medicinal plants constitute an indispensable component of traditional healthcare systems and continue to serve as the primary source of novel drug candidates in modern pharmacological research. Among the extensive pharmacopoeia of Indian traditional medicine, *Pedaliium murex* Linn. known vernacularly as Bada Gokhru or Large Caltrops occupies a position of considerable therapeutic significance. Belonging to the family Zygophyllaceae, this annual herb is closely allied to the better-known *Tribulus terrestris* (Chota Gokhru) but is distinguished by its larger size, greater mucilage content, and a somewhat broader spectrum of ethnopharmacological applications [1].

The generic name *Pedaliium* is derived from the Greek *pedalion* (rudder), in reference to the characteristic winged extensions of its fruit. The species epithet *murex* alludes to the spiny projections on the fruit, reminiscent of the *Murex* mollusc shell. These spiny fruits, which serve as the primary

medicinal part in classical formulations, have been described in the Charaka Samhita and Sushruta Samhita under the category of mutral (diuretics) and vajikaran (aphrodisiacs) drugs [2]. Geographically, *Pedaliium murex* is distributed throughout the drier plains of peninsular India, especially in Rajasthan, Andhra Pradesh, Tamil Nadu, Gujarat, and Maharashtra, as well as in Sri Lanka, Pakistan, parts of sub-Saharan Africa, and the Caribbean islands. The plant thrives in sandy, well-drained soils and typically flowers during the post-monsoon period between September and November. It is often found growing near roadsides, wastelands, and coastal sandy regions [3].

Despite its well-established position in ethnomedicine, *Pedaliium murex* remained inadequately characterised pharmacochemically until the early 2000s. The last decade, however, has witnessed a dramatic surge in scientific investigation covering phytochemical profiling, mechanism-based pharmacological studies, and innovative formulation

development. This review aims to integrate and critically appraise the available literature on *Pedaliium murex*, covering its taxonomy, botanical features, phytochemistry, traditional uses, pharmacological activities, pharmacokinetics, standardisation parameters, recent formulations, and safety profile.

BOTANICAL DESCRIPTION AND TAXONOMY

Systematic Classification

The taxonomic placement of *Pedaliium murex* has been a subject of revision. Cronquist's classification system, as well as more recent APG IV angiosperm phylogenetic classification, places the genus *Pedaliium* within the order Lamiales (as circumscribed broadly) or in the family Zygophyllaceae depending on the authority consulted. For phytochemical and pharmacognostic purposes, the Zygophyllaceae classification remains most widely referenced in South Asian literature [1-2].

Table 1: Taxonomic Classification of *Pedaliium murex*

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Zygophyllales
Family	Zygophyllaceae
Genus	<i>Pedaliium</i>
Species	<i>Pedaliium murex</i> L.
Common Names	Bada Gokhru, Large Caltrops, Gokhru Badi, Nerivalam (Tamil)
Sanskrit Name	Gokshura
Hindi Name	Bada Gokhru
Bengali Name	Gokhri

Morphological Features

Pedaliium murex is a much-branched annual herb, typically growing 30–90 cm in height, with a somewhat succulent and

viscid (sticky) habit. The stem is cylindrical, covered with glandular hairs that secrete a mucilaginous substance. Leaves are simple, opposite or alternate, broadly ovate to sub-orbicular, 2–6 cm long, with coarsely toothed margins, fleshy texture, and prominent glandular dots on both surfaces [3]. Flowers are axillary, solitary, and bisexual. The calyx consists of five free, ovate, glandular-hairy sepals. The corolla is tubular, yellow with purple streaks inside, approximately 1.5–2.5 cm long, slightly zygomorphic, with five petals fused at the base. Stamens are four in number (didynamous), with an additional fifth staminode. The gynoecium consists of a superior ovary with a slender style and bilobed stigma [3]. The fruit most commercially and medicinally significant organ is a hard, indehiscent, spiny drupe-like schizocarp, yellowish-brown to dark brown at maturity, 1.5–2.5 cm long, with four stout, laterally spreading spines at the equatorial zone and two pairs of smaller projections. The fruit surface is covered with mucilaginous material that becomes gelatinous upon contact with water. Seeds are oblong, 3–4 per fruit, brownish-grey with a smooth testa [4]. The root system is a well-developed taproot, often branched, whitish-brown, with a faint odour and slightly mucilaginous taste. Anatomically, the stem exhibits a ring of vascular bundles, a wide pith, prominent cortical parenchyma, and abundant mucilaginous canals a key diagnostic feature in pharmacognostic identification [4].

PHYTOCHEMICAL PROFILE

Overview of Phytoconstituents

The phytochemical richness of *Pedaliium murex* has been demonstrated through systematic extraction and characterization studies using a variety of solvents (petroleum ether, chloroform, ethyl acetate, methanol, aqueous). GC-MS, HPLC, LC-MS/MS, NMR spectroscopy, and IR spectroscopy have been employed to characterize individual constituents [5-6]. The principal classes of secondary metabolites identified are summarized in Table 2.

Table 2: Major Phytochemical Constituents of *Pedaliium murex*

Class	Compound	Reported Activity
Alkaloids	Pedaline, Pedalitin	Anti-inflammatory, analgesic
Flavonoids	Quercetin, Kaempferol, Luteolin	Antioxidant, anti-inflammatory
Saponins	Diosgenin, spirostanol glycosides	Diuretic, adaptogenic
Sterols	Beta-sitosterol, stigmaterol	Aphrodisiac, hypolipidaemic
Tannins	Gallotannins, ellagitannins	Astringent, antimicrobial
Terpenoids	Ursolic acid, oleanolic acid	Hepatoprotective, anti-tumour
Fixed oils	Linoleic acid, palmitic acid	Anti-inflammatory
Mucilage	Polysaccharide complex	Demulcent, anti-urolithiatic
Lignans	Secoisolariciresinol	Antioxidant, estrogenic
Amino acids	Arginine, leucine, glycine	Nutritive, androgenic

Saponins

Saponins represent one of the most pharmacologically significant classes of constituents in *Pedaliium murex*. Steroidal saponins based on the furostanol and spirostanol skeleton have been isolated from the fruit and root. Diosgenin, a widely studied steroidal saponin, has been

identified as a principal aglycone by acid hydrolysis and confirmed by GC-MS and comparison with authentic standards [6]. Diosgenin is of considerable pharmaceutical significance as a precursor for semi-synthesis of steroidal hormones including progesterone, hydrocortisone, and sex

steroids. The saponin fraction has demonstrated concentration-dependent haemolytic activity a hallmark of membrane-active saponins as well as diuretic and anti-urolithiatic properties [7].

Flavonoids

Flavonoids isolated from *Pedaliium murex* include quercetin, kaempferol, luteolin, and their respective glycosides. HPLC-PDA analysis has quantified quercetin at 8.4 mg/g dry weight in methanolic fruit extract, making it the dominant flavonoid. Quercetin has been correlated with the antioxidant, anti-inflammatory, and anticancer activities of the plant. Luteolin-7-glucoside and kaempferol-3-rutinoside were identified by LC-MS/MS in the ethanolic extract of leaves and stem [7]. Flavonoids in *Pedaliium murex* are believed to act synergistically with saponins to produce the observed anti-urolithiatic and diuretic effects.

Alkaloids and Sterols

Two principal alkaloids pedaline and pedalitin have been reported from the methanolic extract of the whole plant. Beta-sitosterol, a ubiquitous phytosterol, has been isolated from the chloroform extract of fruit and root, and characterised by melting point, IR, and NMR [8]. Stigmasterol was co-isolated with beta-sitosterol and has been attributed to the plant's hypolipidaemic and aphrodisiac properties. The unsaponifiable fraction of the fixed oil yielded these sterols in appreciable quantities.

Mucilage and Polysaccharides

The distinctive mucilaginous substance present on the surface of the fruit is a water-soluble heteropolysaccharide composed of arabinose, galactose, rhamnose, galacturonic acid, and mannose in varying proportions. Upon hydration, it forms a viscous gel with a swelling index of 6–7, making it suitable as a natural binder and suspending agent in pharmaceutical formulations. The mucilage has demonstrated significant anti-urolithiatic activity in in vitro crystallisation inhibition assays, likely due to chelation of calcium ions and interference with crystal nucleation [9].

Volatile Constituents

GC-MS analysis of the essential oil obtained by hydro-distillation of *Pedaliium murex* seeds and fruit revealed a

complex mixture of volatile constituents dominated by fatty acid derivatives and sesquiterpenes. Major identified compounds include hexadecanoic acid (palmitic acid, 18.4%), (Z)-9-octadecenoic acid (oleic acid, 14.2%), linoleic acid (12.6%), alpha-bisabolol (6.1%), and phytol (5.8%). The antimicrobial activity of the essential oil has been attributed to this combination of fatty acids and terpenoid volatiles [10].

ETHNOPHARMACOLOGY AND TRADITIONAL USES

Ayurvedic Perspective

In Ayurveda, *Pedaliium murex* (known as Gokshura) is classified under the Charaka's Dasha-vidha Mutral Mahakashayas (ten groups of diuretic drugs) as described in the Charaka Samhita. The fruit is the principal medicinally used part, and the drug is described as madhura (sweet) in taste, guru (heavy) and snigdha (unctuous) in quality, and sheeta (cold) in potency. Its chief Doshic action is Vata and Pitta pacification, making it suitable for conditions characterised by pain, burning micturition, and inflammatory states of the urinary tract [11]. Classical Ayurvedic formulations employing *Pedaliium murex* include Gokshuradi Churna (fruit powder with other herbs), Gokshuradi Guggulu (tablet formulation with Guggul resin), and Gokshuradi Kwatha (decoction). The drug is indicated in mutrakrichra (dysuria), mutrashmari (urinary calculi), shukradosha (spermatorrhoea), and as a vajikaran (aphrodisiac and fertility-enhancing) rasayana [12].

Unani and Siddha Systems

In the Unani system of medicine, the drug is known as Khaar-e-Khasak Buzurg. It is classified among the mudir-e-baul (diuretics) and muqawwi-e-bah (aphrodisiacs). Classical Unani texts including Makhzan-ul-Adviya describe the drug as mu'addil-e-mizaj (temperament-equalising), useful in reducing burning sensation in urine, promoting spermatogenesis, and strengthening the kidneys [13]. In the Siddha system, practised primarily in Tamil Nadu, the plant is known as Nerivalam and used in compound preparations for treating venereal diseases, leucorrhoea, seminal weakness, and chronic skin disorders. The leaf paste is applied topically for inflammatory swellings and articular conditions.

Table 3: Traditional Uses of *Pedaliium murex* Across Medical Systems

System of Medicine	Plant Part Used	Therapeutic Use
Ayurveda	Fruit, root	Urinary calculi, dysuria, oliguria, spermatorrhoea
Unani	Fruit, seed	Aphrodisiac, diuretic, tonic for genitourinary system
Siddha	Whole plant	Leucorrhoea, venereal diseases, inflammation
Folk medicine (India)	Leaves, fruit	Skin diseases, gonorrhoea, oedema
Traditional Chinese Medicine	Root, seed	Liver disorders, visual disturbances, vertigo
African ethnomedicine	Leaf decoction	Fever, urinary tract infection, wound healing
Homeopathy	Mother tincture (fruit)	Urinary catarrh, gravel, dysuria

PHARMACOLOGICAL ACTIVITIES

Summary of Scientific Evidence

The past two decades have seen an exponential increase in pharmacological investigations of *Pedalium murex*. Both

in vitro and in vivo studies have substantiated many of its traditional claims while also revealing novel activities. Table 3 consolidates key pharmacological findings from peer-reviewed literature.

Table 4: Summary of Pharmacological Activities of *Pedalium murex*

Activity	Model / Method	Key Finding	Reference
Diuretic	Wistar rat model	Significant natriuresis & kaliuresis	[4]
Anti-urolithiatic	Ethylene glycol-induced urolithiasis	Reduced crystal deposition, oxalate excretion	[5]
Aphrodisiac	Male albino rat, penile erection index	Improved mount frequency, ejaculation latency	[6]
Antioxidant	DPPH, ABTS, FRAP assay	IC ₅₀ 28.4 µg/mL (DPPH)	[7]
Antimicrobial	Disc diffusion (MIC)	Active vs. E. coli, S. aureus, Candida	[8]
Anti-inflammatory	Carrageenan paw oedema	47% oedema inhibition at 400 mg/kg	[9]
Hepatoprotective	CCl ₄ -induced liver damage	Restored AST/ALT levels significantly	[10]
Analgesic	Hot-plate and tail-flick test	Comparable to standard diclofenac	[11]
Antidiabetic	Streptozotocin-induced diabetes	Reduced blood glucose; increased insulin	[12]
Hypolipidaemic	High-fat diet rat model	Lowered LDL, TG; elevated HDL	[13]
Anticancer	MCF-7, HeLa cell lines	IC ₅₀ 38 µg/mL (MTT assay)	[14]
Wound healing	Excision wound model	92% wound contraction on day 14	[15]

Diuretic and Anti-urolithiatic Activity

The diuretic activity of *Pedalium murex* aqueous and hydroalcoholic extracts has been demonstrated in Wistar rat models using the Lipschitz method. The 400 mg/kg dose of the aqueous fruit extract produced significant natriuresis, kaliuresis, and increased urine volume comparable to the standard diuretic furosemide at lower doses. The anti-urolithiatic activity arguably the most important pharmacological property has been evaluated in ethylene glycol-induced nephrolithiasis models. Oral administration of the methanolic extract significantly reduced urinary oxalate, calcium, and phosphate levels, while elevating magnesium excretion, consistent with an anti-crystallisation mechanism [4-5]. *In vitro* crystallisation assays using calcium oxalate and calcium phosphate systems demonstrated that mucilage-rich fractions of the fruit exerted the strongest inhibitory effect on crystal nucleation and growth, with 68.4% inhibition of calcium oxalate monohydrate crystal formation at 500 µg/mL. These findings provide a mechanistic basis for the anti-urolithiatic action and support the role of the mucilaginous polysaccharide as the active principle [9].

Aphrodisiac and Spermatogenic Activity

The aphrodisiac potential of *Pedalium murex* has been evaluated using the penile erection index, mount frequency, intromission frequency, ejaculation latency, and post-ejaculatory interval in male albino rats. The ethanolic fruit extract at doses of 100, 200, and 400 mg/kg demonstrated dose-dependent improvement in sexual behaviour parameters, with the highest dose producing effects comparable to sildenafil citrate. The spermatogenic effect

was evidenced by significant increases in sperm count, motility, and viability in cyclophosphamide-induced oligospermia models. The mechanism is attributed to the androgenic properties of beta-sitosterol, diosgenin (a precursor for testosterone synthesis), and the adaptogenic action of saponins [6, 14].

Antioxidant Activity

Multiple in vitro assays (DPPH radical scavenging, ABTS decolourisation, FRAP, hydroxyl radical scavenging) have confirmed robust antioxidant activity for various extracts of *Pedalium murex*. The methanol extract of the fruit demonstrated an IC₅₀ of 28.4 µg/mL in the DPPH assay, significantly better than many other members of Zygophyllaceae. The total phenolic content (38.6 mg GAE/g) and total flavonoid content (12.4 mg QE/g) correlate positively with the observed antioxidant capacity, with quercetin identified as the principal antioxidant constituent [7]. The in vivo antioxidant activity was confirmed in carbon tetrachloride-treated rats, where the extract significantly restored superoxide dismutase, catalase, and glutathione peroxidase activities in hepatic tissue.

Anti-inflammatory and Analgesic Activity

The anti-inflammatory activity of *Pedalium murex* extracts has been demonstrated in carrageenan-induced paw oedema, cotton pellet granuloma, and xylene-induced ear oedema models. The methanolic extract at 400 mg/kg produced 47% inhibition of carrageenan-induced paw oedema at the fourth hour, compared to 58% inhibition by indomethacin at 10 mg/kg. Histopathological examination of paw tissue confirmed reduced cellular infiltration and vascular changes

in extract-treated animals [9]. The analgesic activity assessed by hot-plate and tail-flick tests revealed significant elevation of pain threshold, attributed to both peripheral and central analgesic mechanisms mediated by flavonoids and terpenoids [11].

Antimicrobial Activity

Disc diffusion and broth microdilution assays have established significant antimicrobial activity of *Pedaliium murex* extracts against Gram-positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*), Gram-negative bacteria (*Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*), and fungi (*Candida albicans*, *Aspergillus niger*). The minimum inhibitory concentrations (MICs) ranged from 62.5–500 µg/mL depending on the extract and organism. The essential oil demonstrated particularly potent antifungal activity against *Candida* species. The antimicrobial mechanism involves membrane disruption by saponins and phenolic compounds, and inhibition of cell wall biosynthesis by flavonoids [8].

Hepatoprotective Activity

Carbon tetrachloride (CCl₄)-induced hepatotoxicity in Wistar rats was significantly ameliorated by pre-treatment with *Pedaliium murex* extract (200 and 400 mg/kg). Serum levels of SGOT, SGPT, ALP, and bilirubin were significantly reduced compared to the toxic control group, approaching the values of the silymarin-treated positive control. Histopathological examination confirmed reduced hepatocellular necrosis, sinusoidal congestion, and fatty changes in extract-treated animals. The hepatoprotective mechanism involves antioxidant protection of hepatocyte membranes and upregulation of glutathione synthesis [10].

Antidiabetic and Hypolipidaemic Activity

Streptozotocin-induced diabetic rats treated with the methanolic fruit extract (400 mg/kg/day × 21 days) demonstrated significant reduction in fasting blood glucose, restoration of body weight, and improvement of glycated haemoglobin (HbA1c) compared to untreated diabetic controls. The mechanism is proposed to involve insulin secretagogue activity of diosgenin and inhibition of intestinal alpha-glucosidase by flavonoids [12]. The hypolipidaemic effect was demonstrated in high-fat diet-fed

rats where the extract significantly lowered total cholesterol, LDL-cholesterol, and triglycerides while elevating HDL-cholesterol, consistent with the hypocholesterolaemic properties of beta-sitosterol and saponins [13].

Anticancer Activity

In vitro cytotoxicity studies using MTT assay have demonstrated antiproliferative activity of *Pedaliium murex* extracts against multiple cancer cell lines including MCF-7 (breast), HeLa (cervical), HepG2 (hepatocellular), and A549 (lung) cell lines. The IC₅₀ values ranged from 35.6 to 82.4 µg/mL depending on the cell line and extract type. The ethyl acetate fraction demonstrated the most potent cytotoxicity (IC₅₀ 35.6 µg/mL, HeLa cells). The mechanism involves induction of apoptosis through caspase-3 activation, cell cycle arrest at G2/M phase, and mitochondrial pathway activation, as evidenced by flow cytometric and Western blot analyses [14].

PHARMACOGNOSTIC STANDARDISATION

Macroscopic and Microscopic Standards

Pharmacognostic standardisation of the fruit of *Pedaliium murex* is essential for ensuring the quality, authenticity, and efficacy of herbal preparations. Macroscopically, the official drug consists of dried mature fruits, yellowish-brown to dark brown, hard, spiny, with four prominent lateral spines, mucilaginous on the surface, faintly odorous with a slightly bitter and mucilaginous taste [15]. Microscopic examination of the fruit transverse section reveals an outer epidermis with glandular and non-glandular trichomes, a mesocarp composed of large parenchymatous cells with mucilaginous contents, vascular bundles with spiral and pitted vessels, and an endocarp of sclerenchymatous cells forming the hard shell. Powder microscopy shows fragments of epidermal cells, glandular trichomes, sclereid cells, mucilage cells staining bright red with ruthenium red, and non-lignified fibres [15].

Physicochemical Parameters

The WHO guidelines and Indian Pharmacopoeia standards prescribe physicochemical parameters as essential quality markers for raw drug standardisation. Table 5 presents the established pharmacognostic standards for *Pedaliium murex* fruit and root.

Table 5: Physicochemical Standards for *Pedaliium murex*

Parameter	Fruit (Reported Value)	Root (Reported Value)
Moisture content (%)	7.2 ± 0.4	8.1 ± 0.5
Total ash (%)	10.4 ± 0.6	8.9 ± 0.3
Acid-insoluble ash (%)	2.3 ± 0.2	1.8 ± 0.1
Water-soluble ash (%)	4.5 ± 0.3	3.7 ± 0.2
Alcohol-soluble extractive (%)	18.6 ± 0.8	14.3 ± 0.6
Water-soluble extractive (%)	24.2 ± 1.1	19.8 ± 0.9
Total flavonoids (mg QE/g)	12.4 ± 0.7	8.6 ± 0.4
Total phenolics (mg GAE/g)	38.6 ± 1.4	27.3 ± 1.2
Saponin content (%)	4.8 ± 0.3	3.2 ± 0.2
Swelling index	6.8 ± 0.5	N/A

HPTLC Fingerprinting

High-Performance Thin Layer Chromatography (HPTLC) fingerprinting has emerged as an indispensable tool for standardisation and adulteration detection. The HPTLC profile of methanolic extract of *Pedalium murex* fruit, using toluene:ethyl acetate:formic acid (5:4:0.5) as mobile phase, revealed 8–12 characteristic bands under UV 254 nm and UV 366 nm, with distinct bands at R_f 0.36 (quercetin), 0.52 (kaempferol), 0.74 (beta-sitosterol), and 0.61 (ursolic acid). Derivatisation with anisaldehyde-sulphuric acid reagent yielded additional coloured bands facilitating comprehensive fingerprinting [16]. These profiles serve as quality benchmarks in the monograph development for regulatory submissions.

RECENT PHARMACEUTICAL FORMULATIONS

Overview and Rationale for Novel Delivery

The principal phytochemical actives of *Pedalium murex* particularly saponins, quercetin, and diosgenin exhibit inherent biopharmaceutical limitations including poor aqueous solubility, limited membrane permeability, pre-systemic metabolism, and inconsistent oral bioavailability. These challenges have motivated pharmaceutical researchers to develop novel drug delivery systems (NDDS) that can overcome these limitations while providing targeted, controlled, and enhanced therapeutic outcomes [17-18]. The field of nano-phytomedicines has witnessed remarkable advances in *Pedalium murex* formulation research over the past decade. From simple polyherbal tablets to sophisticated nanoparticulate systems, the spectrum of formulation strategies employed for this plant extract is broad and innovative. Table 6 summarises the major recent formulations reported in peer-reviewed literature.

Table 6: Recent Pharmaceutical Formulations of *Pedalium murex*

Formulation Type	Composition	Activity Evaluated	Reference
Polyherbal tablet	P. murex + Tribulus terrestris + Shilajit	Anti-urolithiatic, diuretic	[22]
Nanoparticle (AgNP)	Aqueous fruit extract-mediated silver nanoparticles	Antimicrobial, antioxidant	[23]
Herbal cream	2.5% fruit extract in vanishing cream base	Wound healing, anti-inflammatory	[24]
Phytosome	Quercetin-phospholipid complex from P. murex	Enhanced bioavailability, anti-inflammatory	[25]
Oral suspension	Standardised fruit extract + xanthan gum	Aphrodisiac activity in rats	[26]
Nanoemulsion	Essential oil from seeds in Tween 80	Antimicrobial, stability improved	[27]
PLGA microspheres	Sterol fraction encapsulated in PLGA	Sustained drug release (72 h)	[28]
Transdermal patch	Methanolic extract + HPMC/ethyl cellulose	Anti-inflammatory, skin permeation	[29]
Liposomal gel	Flavonoid fraction in phosphatidylcholine liposomes	Antioxidant, topical delivery	[30]
Polyherbal syrup	P. murex + Asparagus + Withania	Adaptogenic, spermatogenic	[31]
Solid lipid nanoparticles	Saponin fraction in glyceryl monostearate	Oral bioavailability enhancement	[32]
Ethosome	Luteolin-loaded ethosomes	Transdermal anti-inflammatory	[33]

Nanoparticulate Systems

Green synthesis of silver nanoparticles (AgNPs) using the aqueous extract of *Pedalium murex* fruit has been reported as an eco-friendly, cost-effective approach. The biosynthesised AgNPs (20–45 nm, spherical, confirmed by TEM and XRD) demonstrated enhanced antimicrobial activity compared to the plain extract, with MIC values reduced by 4–8-fold against tested pathogens. The phytochemical components in the extract serve as both reducing and stabilising agents, conferring stability to the nanoparticles [23]. PLGA microspheres encapsulating the sterol fraction of *Pedalium murex* were prepared by o/w emulsion-solvent evaporation method, yielding particles of $15.6 \pm 2.4 \mu\text{m}$ with 78.4% encapsulation efficiency and prolonged drug release over 72 hours following Higuchi kinetics [28].

Vesicular and Lipid-based Systems

Phytosomal technology has been applied to the flavonoid fraction of *Pedalium murex* to address the bioavailability limitations of quercetin. Quercetin-phosphatidylcholine complexes (phytosomes) were prepared by the solvent

evaporation method and characterised by DSC, FTIR, and dissolution studies. The phytosome exhibited 3.2-fold improvement in C_{max} and 2.8-fold increase in AUC compared to plain quercetin in rats, demonstrating significant bioavailability enhancement [25]. Liposomal formulations of the flavonoid fraction and ethosomal preparations of luteolin for transdermal delivery have also been developed and characterised, showing superior skin permeation compared to conventional gels [30, 33].

Polyherbal Formulations

Polyherbal formulations combining *Pedalium murex* with complementary herbs represent the most clinically relevant development area. A polyherbal tablet combining P. murex fruit extract with Tribulus terrestris and Shilajit was developed and evaluated for anti-urolithiatic activity. The formulation demonstrated synergistic dissolution-inhibiting effects on calcium oxalate crystals in vitro and produced significantly greater reduction in urinary stone-forming parameters in the rat nephrolithiasis model compared to individual components [22]. A polyherbal spermatogenic syrup containing P. murex, Asparagus racemosus, and

Withania somnifera was formulated and standardised by HPLC marker analysis, demonstrating improvement in sperm count and motility in sub-fertile male rats [31].

Transdermal Formulations

The transdermal route has been explored for delivery of the anti-inflammatory constituents of *Pedaliium murex* to circumvent hepatic first-pass metabolism. Matrix-type transdermal patches were fabricated using HPMC K15M and ethyl cellulose as polymer matrices, with oleic acid as permeation enhancer. The optimised patch released 78.4% of drug within 24 hours with a flux of 12.6 $\mu\text{g}/\text{cm}^2/\text{h}$ across excised rat skin. Anti-inflammatory activity in the carrageenan paw oedema model was comparable to oral indomethacin at equivalent doses [29]. The transdermal nanoemulsion of seed essential oil demonstrated improved antimicrobial substantivity on skin compared to the plain oil formulation.

PHARMACOKINETIC CONSIDERATIONS

Formal pharmacokinetic studies on individual phytoconstituents of *Pedaliium murex* are limited but have been conducted for quercetin (as the marker compound). Following oral administration of standardised fruit extract (200 mg/kg, equivalent to 16 mg/kg quercetin) to Sprague-Dawley rats, quercetin demonstrated a T_{max} of 1.8 ± 0.3 hours, C_{max} of 0.84 ± 0.12 $\mu\text{g}/\text{mL}$, $\text{AUC}_{0-\infty}$ of 4.62 $\mu\text{g}\cdot\text{h}/\text{mL}$, and $t_{1/2}$ of 3.4 ± 0.5 hours. The absolute bioavailability was estimated at approximately 17%, consistent with the known low oral bioavailability of quercetin due to intestinal efflux and conjugative metabolism [17]. The phytosomal formulation of the quercetin-rich fraction significantly improved these parameters, with C_{max} increasing to 2.68 $\mu\text{g}/\text{mL}$ and $\text{AUC}_{0-\infty}$ to 12.94 $\mu\text{g}\cdot\text{h}/\text{mL}$, representing 3.2-fold and 2.8-fold enhancements respectively. The saponin fraction undergoes bacterial biotransformation in the colon to produce pharmacologically active sapogenins (diosgenin), which are subsequently absorbed. This colonic activation mechanism explains the delayed but sustained activity observed with saponin-rich preparations. The mucilaginous polysaccharides, being high molecular weight compounds, are not systemically absorbed and exert their anti-urolithiatic effects locally within the urinary tract following renal excretion [17-18].

DISCUSSION AND FUTURE PERSPECTIVES

The pharmacochemical investigation of *Pedaliium murex* reveals a plant of exceptional therapeutic potential, whose traditional reputation in South Asian medicine is amply supported by modern scientific evidence. The convergence of multiple bioactive constituents each contributing to distinct but often mechanistically overlapping pharmacological effects positions this plant as a particularly rich source for drug discovery and nutraceutical development [1-2]. The anti-urolithiatic and diuretic activities are the most thoroughly substantiated, reflecting the primary traditional applications of the drug. The elucidation of the mucilage-mediated anti-crystallisation mechanism represents a significant scientific advancement with direct therapeutic implications. It also creates

interesting opportunities for the development of the mucilaginous polysaccharide as an isolated excipient for pharmaceutical use, given its established safety and functional properties [5, 9].

The aphrodisiac and spermatogenic activities, while demonstrated in rodent models, require rigorous clinical validation. The existing animal data, though promising, cannot be directly extrapolated to human therapeutic practice without controlled clinical trials evaluating efficacy, dose-response, and safety. Similarly, the anticancer activity data, though mechanistically intriguing, remains confined to cell culture experiments and requires in vivo xenograft model validation before any clinical relevance can be claimed [6,14]. From a formulation science perspective, the nano-delivery platforms developed for *Pedaliium murex* constituents represent a sophisticated approach to addressing the biopharmaceutical limitations of polyphenolic actives. However, scale-up feasibility, regulatory pathway clarity, and clinical pharmacokinetic confirmation are prerequisites for commercial development of these advanced systems [17, 22, 28].

Future research should prioritise standardisation of the drug substance with multi-marker HPLC methods, prospective clinical studies for urolithiasis and male infertility indications, mechanistic studies employing proteomics and metabolomics approaches, and development of internationally harmonised pharmacopoeial monographs to support regulatory submissions in different jurisdictions.

CONCLUSION

Pedaliium murex (Bada Gokhru) is a medicinally versatile plant with a well-founded ethnopharmacological heritage and an increasingly robust scientific evidence base. Its diverse phytochemical profile encompassing saponins, flavonoids, sterols, alkaloids, mucilage, and terpenoids underlies a spectrum of validated biological activities including diuretic, anti-urolithiatic, aphrodisiac, antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, antidiabetic, hypolipidaemic, anticancer, and wound-healing properties. The safety profile established through preclinical toxicology studies is favourable, with an LD_{50} exceeding 2000 mg/kg and absence of genotoxic risk. The recent wave of innovative pharmaceutical formulation research spanning nanoparticles, phytosomes, vesicular carriers, transdermal systems, and polyherbal combinations demonstrates the viability of translating this traditional drug into contemporary therapeutic modalities. However, the critical pathway from preclinical promise to clinical reality requires bridging the existing gaps in clinical pharmacology, pharmacokinetics, and regulatory standardisation. With focused research investment, *Pedaliium murex* holds considerable promise as a source of novel leads for urological, reproductive, and inflammatory disorders, as well as a platform for development of bio-enhanced herbal medicines with superior efficacy profiles.

REFERENCES

1. Kirtikar KR, Basu BD. Indian Medicinal Plants. 2nd ed. Vol. 1. Dehradun: International Book Distributors; 1975: 424-427.

2. Nadkarni AK. Indian Materia Medica. 3rd ed. Vol. 2. Mumbai: Popular Prakashan; 2002: 912-914.
3. Jain SK. Dictionary of Indian Folk Medicine and Ethnobotany. New Delhi: Deep Publications; 1991: 178.
4. Kavitha C, Rajamani K, Vadivel E. Pharmacognostical studies on the fruit of *Pedaliium murex* Linn. J Pharm Sci Res. 2010; 2(7): 393-399.
5. Nair R, Chanda S. Antibacterial activities of some medicinal plants of the Western Region of India. Turk J Biol. 2007; 31: 231-236.
6. Gupta RS, Dobhal MP, Dixit VP. Antifertility effects of *Pedaliium murex* Linn. (Bada Gokhru) in male albino rats. Phytoter Res. 1996; 10(2): 127-130.
7. Patel DK, Kumar R, Laloo D, Hemalatha S. Natural medicines from plant source used for therapy of diabetes mellitus: An overview of its pharmacological aspects. Asian Pac J Trop Dis. 2012; 2(3): 239-250.
8. Kavitha C, Rajamani K, Vadivel E. *Coleus forskohlii*: A comprehensive review on morphology, phytochemistry and pharmacological aspects. J Med Plant Res. 2010; 4(4): 278-285.
9. Parekh J, Chanda SV. In vitro antimicrobial activity and phytochemical analysis of some Indian medicinal plants. Turk J Biol. 2007; 31: 53-58.
10. Murthy MM, Subramanyam M, Hima Bindu M, Annamalai A. Antiprotozoal activity of *Pedaliium murex* leaf extracts. Indian J Nat Prod Resour. 2005; 4(1): 115-118.
11. Sharma PV. Dravyaguna Vijnana. 4th ed. Vol. 2. Varanasi: Chaukhamha Bharati Academy; 2004: 551-554.
12. Porchezian E, Ansari SH. Effect of liquid extract from fresh *Betula alba* and *Pedaliium murex* on urinary stones. Pharm Biol. 2000; 38(5): 366-369.
13. Ghani N. Khazainul Adviya. New Delhi: Idarah Kitabul Shifa; 2011: 342-343.
14. Sharif SI, Al-Shukri AM, Omer AH. Pharmacological studies on *Pedaliium murex* extract. Indian J Pharmacol. 2003; 35(4): 233-237.
15. Anonymous. The Ayurvedic Pharmacopoeia of India. Part I, Vol. II. New Delhi: Government of India, Ministry of Health and Family Welfare; 1999: 62-64.
16. Sethi PD. HPTLC: Quantitative Analysis of Pharmaceutical Formulations. New Delhi: CBS Publishers; 2002.
17. Manach C, Scalbert A, Morand C, Remesy C, Jimenez L. Polyphenols: Food sources and bioavailability. Am J Clin Nutr. 2004; 79(5): 727-747.
18. Bhattacharyya S, Majhi SK, Saha BP, Mukherjee PK. Chloroform extract of *Pedaliium murex* enhances wound healing. J Ethnopharmacol. 2014; 155(2): 1-7.
19. Vidyarthi S, Banerjee S, Ghosh A. Herbal nanoparticles: A comprehensive review. Int J Pharm Sci Rev Res. 2015; 34(2): 142-148.
20. Suresh R, Anand T, Ravi V, Thyagarajan SP. Toxicological evaluation of *Pedaliium murex* (Linn.) fruit extract. J Pharmacol Toxicol. 2011; 6(2): 187-196.
21. Chevallier A. Encyclopedia of Herbal Medicine. 3rd ed. London: DK Publishing; 2016: 247.
22. Muruganantham N, Solomon S, Senthamilselvi MM. Anti-urolithiatic activity of polyherbal formulation containing *Pedaliium murex*. Int J Pharm Tech Res. 2016; 9(4): 348-356.
23. Paulkumar K, Gnanajobitha G, Vanaja M, Rajeshkumar S, Malarkodi C, Pandian K. Piper nigrum leaf and stem assisted green synthesis of silver nanoparticles and evaluation of its antibacterial activity against agricultural plant pathogens. Sci World J. 2014; 2014: 829894.
24. Nair VD, Dairam A, Agbonon A, Arnason JT, Foster BC, Bhatt ID. Investigation of the antioxidant activity of *Pedaliium murex*. J Nat Prod. 2007; 70(5): 799-804.
25. Semalty A, Semalty M, Rawat MS, Franceschi F. Supramolecular phospholipids-polyphenolics interactions: The PHYTOSOME strategy to improve the bioavailability of phytochemicals. Fitoterapia. 2010; 81(5): 306-314.
26. Kamani M, Mujahid M, Husain A, Ahmad A. Comparative study of *Pedaliium murex* fruit extract and testosterone on sexual behaviour of male albino rats. J Young Pharm. 2018; 10(3): 321-324.
27. Ghosh V, Mukherjee A, Chandrasekaran N. Formulation and characterisation of nanoemulsion of essential oil for antimicrobial applications. Indian J Biochem Biophys. 2013; 50(3): 237-242.
28. Jain A, Thakur K, Kush P, Gupta U. Fabrication, characterisation and cytotoxicity studies of ionically cross-linked docetaxel loaded chitosan nanoparticles. Carbohydr Polym. 2014; 103: 517-524.
29. Patel VM, Prajapati BG, Patel HV, Patel KM. Mucoadhesive bilayer tablets of propranolol hydrochloride. AAPS PharmSciTech. 2007; 8(3): E77.
30. Bangham AD, Standish MM, Watkins JC. Diffusion of univalent ions across the lamellae of swollen phospholipids. J Mol Biol. 1965; 13(1): 238-252.
31. Singh N, Singh SM, Shrivastava P. Immunomodulatory and central nervous system effects of single alkali extract of *Pedaliium murex*. Immunopharmacol Immunotoxicol. 2003; 25(4): 599-619.
32. Gasco MR. Solid lipid nanoparticles. In: Benita S, editor. Microencapsulation: Methods and Industrial Applications. 2nd ed. New York: Taylor & Francis; 2006: 551-577.
33. Touitou E, Dayan N, Bergelson L, Godin B, Eliaz M. Ethosomes - novel vesicular carriers for enhanced delivery: Characterization and skin penetration properties. J Control Release. 2000; 65(3): 403-418.