Cyperus rotundus Linn.: Phytochemical Constituents and Pharmacological Activities

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Abstract

Cyperus rotundus L., commonly known as purple nut sedge or Indian cyperus, is a perennial herb widely distributed across tropical and subtropical regions. This plant has been extensively used in traditional medicine systems for centuries. This review consolidates current knowledge on the plant's botanical characteristics, phytochemical constituents, and diverse pharmacological actions including antioxidant, anti-inflammatory, antimicrobial, anticonvulsant, hepatoprotective, antiulcer, and antidiabetic properties. Recent research has demonstrated the efficacy of various extracts and isolated compounds in treating several pathological conditions. This paper provides a comprehensive overview of the pharmacological mechanisms of action, highlighting the therapeutic potential of Cyperus rotundus and identifying areas for future research.

Keywords: Nut grass, Medicinal plant, Bioactive compounds,Therapeutic potential

1. Introduction

The integration of traditional medicine with modern pharmacological science has opened new avenues for drug discovery. Cyperus rotundus L. (Family: Cyperaceae) is one such medicinal plant that has attracted considerable scientific attention owing to its widespread traditional use and demonstrated biological activities. The rhizomes and roots of this plant have been used in Ayurvedic, Chinese, and Unani medicine for the treatment of various ailments including pain, inflammation, seizures, and digestive disorders.

The escalating interest in natural remedies, coupled with the emergence of drug-resistant pathogens and adverse effects associated with synthetic drugs, has necessitated extensive pharmacological evaluation of medicinal plants. Cyperus rotundus presents an excellent model for phytopharmacological investigation due to its rich phytochemical composition and established ethnopharmacological use. This review aims to provide a comprehensive analysis of the botanical characteristics, phytochemical constituents, and diverse pharmacological properties of this important medicinal plant.

2. Botanical Description and Distribution

2.1 Taxonomic Classification

Cyperus rotundus belongs to the family Cyperaceae, a monocotyledonous family containing approximately 400 genera and 4000 species. The taxonomic classification is as follows:

Rank	Classification	Common Names
Kingdom	Plantae	Purple nut sedge
Family	Cyperaceae	Cyperus, Musta
Species	C. rotundus	Indian cyperus

2.2 Morphological Characteristics

Cyperus rotundus is a persistent perennial herb with the following morphological features:

- Height: 20–45 cm tall
- Stem: Trigonous (three-angled), leafy culms
- Leaves: Linear, channeled, 30–60 cm long, sheathing base
- Inflorescence: Compound umbels with dark purple spikelets
- Rhizomes: Globose to ovoid tubers, aromatic, dark brown to purplish
- Flowers: Small, purplish-brown, hermaphrodite

2.3 Geographic Distribution

Cyperus rotundus is native to India and other tropical regions of Asia and Africa. It has become widely distributed in warm temperate zones worldwide, including South Asia, Southeast Asia, Africa, and Central America. The plant grows preferentially in moist habitats, particularly in cultivated areas, waste lands, and agricultural fields. In many regions, it is considered an invasive weed due to its aggressive rhizomatous growth and resistance to herbicides.

3. Phytochemical Composition

3.1 Major Chemical Constituents

Cyperus rotundus contains a diverse array of chemical compounds. The rhizomes are particularly rich in essential oils and other bioactive metabolites. Major chemical constituents identified
include:

1. Essential Oils (0.5–1% v/w): Includes alpha-pinene, beta-pinene, limonene, myrcene, and other monoterpenes
2. Sesquiterpenes: Cyperotundone, isocyperotundone, and related compounds
3. Alkaloids: Cyperine and other alkaloid derivatives
4. Phenolic Compounds: Including flavonoids and phenolic acids
5. Glycosides: Various cardiac and cyanogenic glycosides
6. Carbohydrates and Proteins: Including starch and amino acids

3.2 Key Bioactive Compounds

Among the numerous phytochemical constituents, several key compounds have been identified as primarily responsible for the biological activities of Cyperus rotundus. The essential oil fraction contains significant amounts of monoterpenes such as (α)-pinene and (β)-myrcene, which contribute to the antimicrobial and antioxidant properties. Sesquiterpenes, particularly cyperotundone (2,5-diethyl-2,5-dihydrofuran-2,5-dione), represent another important class of bioactive compounds demonstrating significant anticonvulsant and anti-inflammatory effects. Recent phytochemical investigations have also revealed the presence of various flavonoid compounds and phenolic acids, which possess strong antioxidant capacity and free radical scavenging properties.

4. Pharmacological Actions

4.1 Antioxidant Activity

The antioxidant activity of Cyperus rotundus has been extensively documented in numerous in vitro studies. The ethanolic, methanolic, and aqueous extracts of the rhizomes display significant free radical scavenging ability against 1,1-diphenyl-2-picrylhydrazyl (DPPH), superoxide radicals, and hydrogen peroxide. The antioxidant potential is attributed to the high content of polyphenolic compounds and essential oils. The IC50 values of various extracts typically range from 15–50 μg/mL in DPPH assays, indicating potent antioxidant effects. The mechanism involves electron donation to reactive oxygen species (ROS), thereby preventing oxidative stress-induced cellular damage and contributing to the cytoprotective effects of the plant.

4.2 Anti-inflammatory Activity

Cyperus rotundus exhibits potent anti-inflammatory effects through multiple mechanisms of action. In animal models of inflammation, extracts of the plant effectively inhibit paw edema induced by carrageenan, dextran, and histamine. The anti-inflammatory action is mediated through the suppression of pro-inflammatory mediators including tumor necrosis factor-alpha (TNF-α), interleukin-1β (IL-1β), and interleukin-6 (IL-6). The plant also inhibits the production of prostaglandins and leukotrienes by suppressing cyclooxygenase (COX) and lipoxygenase (LOX) enzymes. Sesquiterpenes and other secondary metabolites present in the plant modulate the nuclear factor-kappa B (NF-κB) signaling pathway, a critical regulator of inflammatory gene expression.

4.3 Antimicrobial Activity

The essential oil and various extracts of Cyperus rotundus demonstrate significant antimicrobial activity against a wide spectrum of bacteria and fungi. The essential oil exhibits inhibitory activity against Gram-positive bacteria including Staphylococcus aureus and Bacillus subtilis, as well as Gram-negative bacteria such as Escherichia coli and Pseudomonas aeruginosa. Antifungal activity has been demonstrated against Candida albicans, Aspergillus niger, and other pathogenic fungi. The antimicrobial action is primarily attributed to the essential oil components, particularly monoterpenes, which disrupt bacterial cell membranes and inhibit cell wall biosynthesis. The minimum inhibitory concentration (MIC) values typically range from 0.16–34 μL/mL depending on the microorganism and extraction method.

4.4 Anticonvulsant Activity

One of the most significant pharmacological properties of Cyperus rotundus is its anticonvulsant activity, which has been validated through multiple experimental models. In rodent seizure models including pentylenetetrazol (PTZ)-induced seizures and electroshock-induced seizures, the aqueous and ethanolic extracts of the rhizomes

provide significant protection against seizure onset and severity. The anticonvulsant mechanism involves enhancement of gamma-aminobutyric acid (GABA)-mediated neurotransmission by increasing GABA receptor density and function. Additionally, the plant extracts modulate voltage-gated calcium channels and potassium channels, which participate in neuronal excitability. Sesquiterpenes, particularly cyperotundone and related compounds, are considered the primary constituents responsible for the anticonvulsant effects.

4.5 Hepatoprotective Activity

The hepatoprotective potential of Cyperus rotundus has been demonstrated in various experimental models of drug-induced and chemical-induced liver injury. Administration of rhizome extracts to laboratory animals exposed to hepatotoxic agents such as carbon tetrachloride (CCl4), acetaminophen, and other xenobiotics resulted in significant reduction of liver damage. The protection is evidenced by decreased serum levels of liver enzymes (alanine aminotransferase [ALT], aspartate aminotransferase [AST], and alkaline phosphatase [ALP]), improved histological appearance of hepatic tissue, and enhanced antioxidant status. The hepatoprotective mechanism involves antioxidant-mediated prevention of lipid peroxidation in hepatocytes, modulation of detoxifying enzyme systems including cytochrome P450, and anti-inflammatory effects that prevent hepatic inflammation.

4.6 Antiulcer Activity

Cyperus rotundus exhibits significant protective effects against gastric ulcer formation in experimental animals. In models of gastric ulceration induced by various agents including ethanol, indomethacin, stress, and Helicobacter pylori, the plant extracts provided substantial protection with reduction in ulcer area and improvement in healing. The antiulcer activity is attributed to multiple mechanisms: (1) suppression of gastric acid secretion and reduction of pepsin activity, (2) enhancement of gastric mucus production, (3) anti-inflammatory effects that prevent mucosal inflammation, (4) antioxidant activity that protects mucosa from oxidative stress, and (5) antimicrobial activity against H. pylori.

4.7 Antidiabetic Activity

Recent investigations have demonstrated the hypoglycemic and antidiabetic potential of Cyperus rotundus in both normal and diabetic experimental animals. Administration of rhizome extracts to streptozotocin (STZ)-induced diabetic rats resulted in significant reduction of blood glucose levels and improvement of glucose tolerance. The aqueous extract demonstrated IC50 values of 47–197 µg/mL for alpha-glucosidase inhibition, indicating competitive inhibition of carbohydratemetabolizing enzymes. The antidiabetic mechanism involves: (1) enhanced insulin secretion from pancreatic beta cells, (2) improved peripheral glucose uptake and utilization, (3) inhibition of carbohydrate-metabolizing enzymes such as alpha-glucosidase and alpha-amylase,
(4) antioxidant protection against beta cell apoptosis, and (5) modulation of lipid metabolism.

4.8 Analgesic Activity

Cyperus rotundus demonstrates analgesic (pain-relieving) properties in various pain models. The plant extracts showed significant reduction of pain response in tail-flick, hot plate, and writhing tests in laboratory animals. The analgesic effect is attributed to the modulation of nociceptive pathways and inhibition of pain mediators. The mechanism may involve: (1) peripheral inhibition of pain mediators, (2) inhibition of COX and LOX pathways reducing prostaglandin and leukotriene synthesis, (3) interaction with opioid receptors, and (4) modulation of serotonergic and monoaminergic systems in the central nervous system.

4.9 Spasmolytic Activity

The rhizomes of Cyperus rotundus possess spasmolytic properties that may be beneficial in gastrointestinal disorders. The plant extracts demonstrate relaxant effects on isolated intestinal smooth muscle preparations. The mechanism involves inhibition of muscarinic receptor activation and modulation of calcium channels, preventing excessive smooth muscle contraction. This property supports the traditional use of the plant for treating abdominal pain and diarrhea.

4.10 Immunomodulatory Activity

Emerging research suggests that Cyperus rotundus possesses immunomodulatory properties that enhance immune function. The plant extracts have been shown to enhance phagocytic activity of macrophages and promote proliferation of lymphocytes. These effects may be mediated through activation of Toll-like receptors and modulation of cytokine production. The immunoenhancing properties may contribute to the traditional use of the plant for improving general health and resistance to infections.

5. Conclusion

Cyperus rotundus is a promising medicinal plant with a diverse array of pharmacological activities supported by scientific evidence. The plant's traditional use in Asian and African medicine systems has been validated through numerous pharmacological studies demonstrating antioxidant, antiinflammatory, antimicrobial, anticonvulsant, hepatoprotective, antiulcer, antidiabetic, and immunomodulatory properties. The phytochemical constituents, particularly essential oils and sesquiterpenes, are responsible for the observed biological activities through multiple mechanisms of action.

Despite the extensive research conducted to date, several areas warrant further investigation. Structure-activity relationship (SAR) studies of the bioactive constituents would facilitate the development of more potent therapeutic agents. Clinical trials in human subjects are needed to validate the efficacy and safety of Cyperus rotundus and its preparations for various therapeutic applications. The standardization of extracts and establishment of quality control parameters would enable the development of standardized herbal formulations with reproducible pharmacological effects. Investigation of potential drug interactions and pharmacokinetic properties would be valuable for clinical translation. Additionally, mechanistic studies at the molecular and cellular levels would elucidate the precise target proteins and signaling pathways involved in the pharmacological effects.

The integration of traditional knowledge with modern pharmacological tools and molecular biology techniques positions Cyperus rotundus as a valuable source for the development of novel therapeutic agents for the treatment of various pathological conditions including neurological disorders, inflammatory diseases, microbial infections, hepatic disorders, and metabolic diseases.

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