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Review Article

From Folk Remedy to Future Pharmacy: Emerging Insights into *Synedrella nodiflora*

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ABSTRACT

Synedrella nodiflora (L.) Gaertn. is a medicinal plant traditionally used in Ayurveda, Unani, Siddha, and other herbal systems for treating inflammation, infections, neurological disorders, and wound healing. A comprehensive literature review was conducted using scientific databases to compile information on the plant's botanical description, phytochemical constituents, extraction methods, pharmacological activities, toxicological profile, and commercial uses. The plant contains major bioactive compounds such as flavonoids, alkaloids, terpenoids, phenolics, and saponins. These constituents exhibit antioxidant, anti-inflammatory, antimicrobial, analgesic, and neuroprotective effects in various in vivo and in vitro studies. Toxicological evaluations demonstrate a favorable safety profile with no significant adverse effects at therapeutic doses. Additionally, *S. nodiflora* shows potential applications in sustainable agriculture and green energy. *Synedrella nodiflora* is a promising source of bioactive compounds with diverse pharmacological properties and a strong safety profile. Future studies focusing on phytochemical standardization, molecular mechanisms, and clinical trials are essential to validate its therapeutic efficacy and facilitate its use in drug development and sustainable agriculture.

INTRODUCTION

Synedrella nodiflora (L.) Gaertn., commonly known as Cinderella weed, nodeweed, or pig's grass, belongs to the family Asteraceae and is the

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sole species within the genus *Synedrella* [1,2]. First formally described by Gaertner in 1791 in *De Fructibus et Seminibus Plantarum* [3], this annual herbaceous plant originates from tropical Americas ranging from Mexico, Central America, the Caribbean to South America [2,4]. Due to human activities and natural dispersal mechanisms, *S. nodiflora* has now become pantropical. It has been widely introduced and naturalized across Asia (including India, China, and Southeast Asia), sub-Saharan Africa, the Pacific Islands (e.g., Fiji, Samoa), and northern Australia, as well as some parts of the United States such as Florida and Hawaii [2,4,5]. Its global distribution reflects both its robust seed dispersal (wind, water, animal fur, and human clothing) and its remarkable ecological adaptability [1,6]. Ecologically, *S. nodiflora* thrives in disturbed habitats such as roadsides, fallow lands, cultivated fields, gardens, and riverbanks up to elevations of approximately 1,200 m above sea level [1,6]. It exhibits rapid germination, a short life cycle of approximately 100–150 days, prolific seed production (thousands per square meter), and tolerance to a wide range of soils and light conditions (from full sun to light shade) [1,6]. These traits have made it an aggressive weed in tropical and subtropical agroecosystems [1]. In traditional medicine, indigenous communities across its introduced and native ranges have notable uses for *S. nodiflora*. In Ghana, the whole plant is consumed as a remedy for epilepsy, threatened abortion, hiccups, laxative purposes, and livestock feed; while in Nigeria, it is employed to manage cardiac disorders and to promote haemostasis in wounds [7]. Southeast Asian practices include consumption of its young leaves as a vegetable in Indonesia, treatment of rheumatism and stomachache via leaf sap blends, poulticing for headaches and leg ulcers in Malaysia, and instillation of sap in ears for earaches [7]. Despite its status as a weed, its

widespread traditional applications and emerging pharmacological findings such as anticonvulsant, sedative, antioxidant, antinociceptive, and insecticidal properties make it a compelling subject for pharmacognostic exploration [7].

Traditional and Medicinal Uses of *Synedrella nodiflora*

1. Ayurveda & Siddha

Synedrella nodiflora, known locally as Poduthalai or Jalapippali, is utilized in Siddha and Ayurvedic systems for its diuretic, febrifuge, antibacterial, and spasmolytic properties. The leaf juice or decoction is traditionally employed to treat leucorrhoea, piles, urinary calculi, dandruff, and externally for wounds, skin infections, and rheumatism [08]. Poultices are applied for joint pain, and leaf sap is instilled in the ear to relieve earache. Its use as a topical remedy for scalp disorders is also documented [06,08]

2. Unani

In Unani medicine, the herb is referenced as Bukkun Booti, used in decoctions for detoxification and addressing hemorrhoids (bleeding piles), epistaxis, cystolithiasis, gonorrhoea, dysuria, febrile states, asthma, bronchitis, arthralgia, and as a postnatal tonic to support maternal recovery [09].

3. Chinese Folk Medicine

Although not officially recorded in Chinese pharmacopoeias, ethnomedical surveys of the region indicate usage of leaf decoctions and poultices for febrile conditions, inflammation, rheumatism, earache, and wound healing mirroring its applications in neighboring systems [10].

4. Homeopathy (Potential)



Although *S. nodiflora* is absent from traditional homeopathic materia medica, its analgesic, anti-inflammatory, sedative, and anticonvulsant activities suggest potential applicability in symptom-based extract dosages for pain, spasm, inflammation, and convulsion-related conditions [09,10].

5. African Traditional Medicine

In West Africa, particularly Ghana and Nigeria, whole-plant decoctions are used clinically to manage epilepsy, convulsions, pain, threatened abortion, hiccups, gastrointestinal disturbances, and hematuria. Leaf sap is frequently applied to

hemostatic wounds, ear infections, and also consumed as a laxative [04,06].

6. Southeast Asian Ethnomedicine

In Indonesia and Malaysia, *S. nodiflora* young leaves are consumed as a vegetable, while leaf extracts treat stomach pain, rheumatism, leg ulcers, headache, and earache, with topical application of sap or poultices [06,10].

7. Ethnoveterinary Uses

Across sub-Saharan Africa, *S. nodiflora* is applied in livestock healthcare, including the treatment of skin wounds and external parasitic infestations [06].

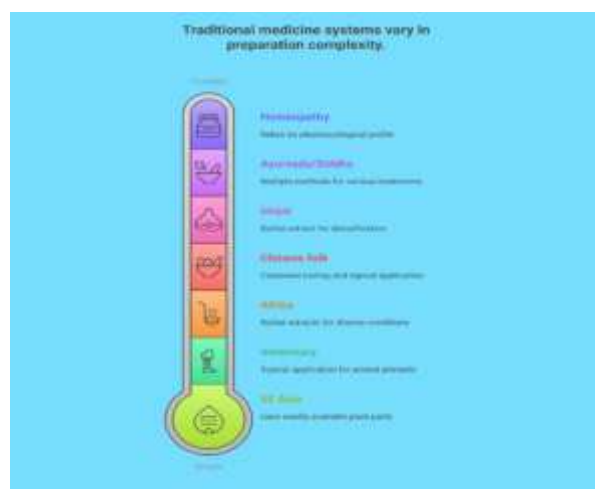


Fig No. 01 - Traditional medicine systems vary in preparation complexity.

Table No. 01 - "Traditional Medicinal Practices by Region and System"

System/Region	Preparation	Primary Indications
Ayurveda/Siddha	Decoction, leaf juice, poultice	Diuresis, fever reduction, antibacterial; skin, wound, scalp, rheumatism treatments [08]
Unani	Decoction	Detoxification; piles, bleeding; urinary, respiratory, joint, and postnatal conditions [09]
Chinese folk	Decoction, poultice	Fever, inflammation, earache, rheumatism, wound healing [10]
Homeopathy (potential)	—	Pain, inflammation, spasms, convulsions—based on known pharmacological profile [09,10]
Africa	Decoction, leaf sap	Convulsions, epilepsy, pain, threatened abortion, hiccups, GI issues, hematuria [04,06]
SE Asia	Vegetable, sap, poultice	Stomach pain, rheumatism, headache, ulcers, earache [06,10]
Veterinary	Poultice	Livestock wound healing, parasitic skin infections [06]

Botanical Description of *Synedrella nodiflora* (L.) Gaertn.

Synedrella nodiflora (L.) Gaertn. is an erect, annual herbaceous plant belonging to the family Asteraceae (Compositae). It typically attains a height of 30–90 cm depending on environmental conditions [12].

Morphology

- **Stem:** The stem is slender, often branched, and covered with fine, short hairs (pubescent). It is green and sometimes slightly tinged with purple, displaying a soft but sturdy texture [12,13].
- **Leaves:** Leaves are simple, alternate, and ovate to lanceolate with serrated margins. The leaf surface is hairy (pubescent), and the leaves are typically 3–8 cm long and 1–4 cm wide. They possess prominent pinnate venation with a slightly petiolate base [12,14]. The leaves emit a mild aromatic odor when crushed [14].
- **Inflorescence:** The flowers are small, yellow, and arranged in axillary and terminal capitula (flower heads). Each capitulum is about 0.8–1.5 cm in diameter and consists of both ray and disc florets, characteristic of the Asteraceae family [12,13]. The ray florets are usually 3–5 in number and ligulate, while disc florets are tubular and bisexual [12].
- **Roots:** The root system is fibrous and shallow, aiding rapid growth and spread in disturbed soils. The roots have moderate branching and exhibit minor secondary thickening [15].
- **Fruit:** The fruit is an achene, small, dry, and one-seeded, with a pappus of fine bristles facilitating wind dispersal. The achenes are typically 1.5–2 mm long and slightly curved,

exhibiting a light brown color upon maturity [12,16].

Growth Habit and Habitat

Synedrella nodiflora is commonly found in tropical and subtropical regions, thriving in a variety of disturbed sites including roadsides, agricultural fields, gardens, riverbanks, and fallow land. It prefers full sun but tolerates partial shade and grows in a wide range of soil types, from sandy to loamy soils with moderate moisture [12,13]. The plant grows rapidly and flowers throughout the year in favorable climates, especially during rainy seasons [14].

Diagnostic Characteristics

- Small, yellow flower heads with 3–5 ray florets
- Serrated ovate-lanceolate leaves with pubescent surfaces
- Slender, branched stems with fine hairs
- Achene fruit with pappus bristles adapted for anemochory (wind dispersal)





Fig.No.02-Leaf and flowers of Ficus carica

Extensive phytochemical analyses of *Syndrella nodiflora* have identified a diverse spectrum of both major and minor secondary metabolites that are responsible for its pharmacological activities. These compounds belong to various chemical classes, including flavonoids, alkaloids, terpenoids, phenolics, and glycosides.

Major Phytochemicals

1. Flavonoids

Flavonoids are among the most abundant constituents of *S. nodiflora*. These include quercetin, kaempferol, luteolin, and apigenin derivatives. These flavonoids exhibit potent antioxidant, anti-inflammatory, and antimicrobial effects, which contribute significantly to the plant's traditional uses [18,19].

2. Alkaloids

The presence of alkaloids, though in moderate quantities, has been documented. These nitrogen-containing compounds are linked to the plant's analgesic and anticonvulsant activities. Identified alkaloids include indole and isoquinoline derivatives that modulate neurological pathways [20].

3. Terpenoids and Essential Oils

Monoterpenes, sesquiterpenes, and triterpenoids have been isolated from *S. nodiflora*. These volatile compounds contribute to the plant's aroma and demonstrate anti-inflammatory, antimicrobial, and insecticidal properties. Essential oil extracts contain constituents such as β -caryophyllene and α -pinene [18,21].

4. Phenolic Compounds

The plant is rich in phenolic acids such as caffeic acid, chlorogenic acid, and gallic acid. These compounds provide strong free radical scavenging capabilities, supporting the plant's antioxidant and wound-healing actions [19,22].

5. Saponins

Saponins detected in *S. nodiflora* exhibit surfactant properties, facilitating cellular membrane interactions. Their anti-inflammatory and immunomodulatory activities have been experimentally verified [23].

Minor Phytochemicals

1. Steroids

Minor amounts of steroidal compounds such as β -sitosterol and stigmasterol are present. These sterols are known to stabilize cell membranes and exhibit anti-inflammatory and hypocholesterolemic effects [24].

2. Glycosides

Cardiac and non-cardiac glycosides have been isolated in trace amounts. Though minor, these compounds may enhance the plant's pharmacological profile through modulation of cardiac and smooth muscle functions [25].

3. Tannins

Tannins, present in smaller concentrations, add to the antimicrobial and astringent properties of the plant, aiding in wound healing and infection control [22].

4. Other Compounds

Additional minor constituents include coumarins, phenylpropanoids, and trace minerals that may contribute synergistically to the overall therapeutic effects [18,25].

- **Flavonoids:** These compounds are abundant in the leaves and are pivotal for reducing oxidative stress and inflammation. In Ayurveda, they are considered crucial for skin health and managing febrile conditions.
- **Alkaloids:** Present throughout the plant but concentrated in roots and leaves; traditional healers use them for neurological ailments, consistent with modern findings on anticonvulsant activity.
- **Terpenoids:** Mostly found in essential oils from leaves and flowers; traditionally used to treat insect bites and microbial infections, their modern insecticidal and antimicrobial roles align with ethnobotanical uses.
- **Phenolic Compounds:** Concentrated in leaves and roots; widely used traditionally to heal wounds and treat ulcers, now exploited for their free radical scavenging properties.
- **Saponins:** Found primarily in leaves and roots; traditionally used to modulate immune responses, consistent with emerging immunomodulatory research.
- **Steroids:** Occur in minor amounts in leaves and stems, traditionally used for inflammation and joint pain; modern research supports their anti-inflammatory potential.
- **Glycosides:** Trace amounts detected in leaves; traditionally used to support cardiovascular and smooth muscle health, matching ongoing pharmacological investigations.
- **Tannins:** Present mainly in leaves and stems, traditionally valued for their antimicrobial and astringent properties, which modern science confirms.

Table No. 02 -Summary of Key Phytochemicals, Bioactivities, and Traditional and Modern Uses of *Synedrella nodiflora*

Compound Class	Examples/ Notable Compounds	Reported Bioactivities	Traditional Uses (Ayurveda, Unani, Siddha, Others)	Modern Uses (Pharmacological Applications)	Reference Numbers
Flavonoids	Quercetin, Kaempferol, Luteolin, Apigenin	Antioxidant, anti-inflammatory, antimicrobial	Used in wound healing, fever reduction, treatment of inflammation; skin disorders, respiratory ailments [18,19]	Applied in antioxidant therapies, anti-inflammatory drugs, antimicrobial formulations	[18,19]
Alkaloids	Indole, Isoquinoline derivatives	Analgesic, anticonvulsant	Treatment of epilepsy, convulsions, pain relief, and	Used as natural anticonvulsants and analgesics in neurological	[20]

			neurological disorders in traditional medicine [20]	disorder management	
Terpenoids	β -Caryophyllene, α -Pinene	Anti-inflammatory, antimicrobial, insecticidal	Employed in traditional medicine for inflammation, infections, insect bites, and as insect repellents [18,21]	Incorporated in anti-inflammatory, antimicrobial drugs and insecticide development	[18,21]
Phenolic Compounds	Caffeic acid, Chlorogenic acid, Gallic acid	Antioxidant, wound healing	Used for treating wounds, ulcers, skin infections, gastrointestinal ailments [19,22]	Basis for antioxidant supplements, topical wound healing agents, anti-ulcer drugs	[19,22]
Saponins	—	Anti-inflammatory, immunomodulatory	Utilized for inflammation, immune support, and detoxification therapies [23]	Explored in immunomodulatory drugs and anti-inflammatory formulations	[23]
Steroids	β -Sitosterol, Stigmasterol	Anti-inflammatory, membrane stabilization	Used in joint pain, inflammation management, and skin conditions in traditional systems [24]	Investigated for anti-inflammatory drug development and cholesterol-lowering therapies	[24]
Glycosides	Cardiac and non-cardiac glycosides	Modulation of cardiac and smooth muscle function	Traditional use in managing muscle spasms, cardiac disorders, and respiratory problems [25]	Studied for potential cardiotonic effects and smooth muscle relaxants	[25]
Tannins	—	Antimicrobial, astringent	Applied in wound care, infection control, diarrhea, and gastrointestinal tract ailments [22]	Used in antimicrobial agents, gastrointestinal treatments, and astringents	[22]

Synedrella nodiflora contains a variety of bioactive compounds, mainly flavonoids, alkaloids, terpenoids, phenolic compounds, saponins, steroids, glycosides, and tannins. Flavonoids (e.g., quercetin, kaempferol) and phenolic acids contribute strong antioxidant, anti-inflammatory, and antimicrobial effects, supporting traditional uses in wound healing, fever

reduction, and skin disorders. Alkaloids provide analgesic and anticonvulsant properties, aligning with its use in epilepsy and pain management. Terpenoids exhibit antimicrobial, anti-inflammatory, and insecticidal activities, reflecting its application in treating infections and insect bites. Saponins and steroids modulate immune responses and inflammation, while

glycosides impact cardiac and smooth muscle functions. Tannins offer antimicrobial and astringent benefits used in gastrointestinal and skin ailments. These phytochemicals justify the plant's widespread traditional applications across Ayurveda, Unani, Siddha, and other herbal systems and are being explored for modern pharmacological uses such as antioxidant therapies, anti-inflammatory drugs, antimicrobial agents, and cardiogenic treatments.

Methods of Extraction of Phytochemicals from *Synedrella nodiflora*

Extraction of bioactive compounds from *Synedrella nodiflora* involves various conventional and modern techniques designed to maximize yield, purity, and biological activity of the constituents. The choice of extraction method depends on the target compounds, plant part used, and intended application.

1. Solvent Extraction

- **Maceration:** This traditional method involves soaking dried and powdered plant material in solvents such as ethanol, methanol, water, or their mixtures at room temperature for several hours or days. The solvent dissolves phytochemicals which are then separated by filtration. Maceration is simple, cost-effective, and widely used for extracting flavonoids, phenolics, and alkaloids [26,27].
- **Soxhlet Extraction:** This technique employs continuous hot solvent extraction using apparatus that recycles solvent over the plant material. Soxhlet extraction efficiently extracts thermostable compounds like terpenoids and steroids, yielding higher extract concentrations in shorter times compared to maceration [28].

- **Ultrasound-Assisted Extraction (UAE):** UAE uses ultrasonic waves to disrupt plant cell walls, enhancing solvent penetration and mass transfer. This method improves extraction efficiency of sensitive compounds such as flavonoids and phenolics while reducing solvent consumption and extraction time [29].

2. Hydrodistillation

- Used mainly for obtaining essential oils, hydrodistillation involves boiling the plant parts (usually leaves and flowers) in water or steam to vaporize volatile compounds. The vapors are condensed and collected as essential oil, rich in terpenoids like β -caryophyllene and α -pinene. This method preserves volatile bioactives and is widely applied in *S. nodiflora* phytochemical studies [30].

3. Supercritical Fluid Extraction (SFE)

- SFE utilizes supercritical CO₂ as a solvent under specific temperature and pressure conditions. It is a green extraction technique that selectively isolates non-polar and moderately polar compounds like steroids and terpenoids with minimal thermal degradation. Though less common, SFE has been explored for *S. nodiflora* for obtaining high-purity bioactives [31].

4. Microwave-Assisted Extraction (MAE)

- MAE applies microwave energy to rapidly heat the solvent and plant matrix, disrupting cells and releasing phytochemicals efficiently. This method reduces extraction time and solvent use while maintaining compound integrity. It is particularly effective for flavonoids and phenolics [32].



5. Fractionation and Purification

- Post-extraction, crude extracts of *S. nodiflora* are often subjected to liquid-liquid partitioning, column chromatography, or preparative HPLC to separate individual compounds or fractions enriched in specific phytochemicals for detailed pharmacological evaluation [33].

Cultivation and Harvesting of *Synedrella nodiflora*

1. Botanical Adaptability and Growth Conditions

Synedrella nodiflora is a fast-growing herbaceous plant native to tropical America but now widely distributed across tropical Asia, Africa, and Oceania. It thrives in warm, humid climates and is found abundantly in open fields, roadsides, agricultural borders, and disturbed soils.

- **Climate:** Prefers tropical to subtropical environments with annual rainfall of 1000–2000 mm and temperatures ranging between 20°C and 35°C [34].
- **Soil:** Grows well in well-drained loamy to sandy soils, though it tolerates poor, acidic, or even slightly alkaline soils. Soil pH between 5.5 and 7.5 is ideal [35].
- **Light:** Being heliophilous, it requires full sun exposure for optimal biomass production [36].

2. Propagation

- *S. nodiflora* is typically propagated by seeds, although it also spreads through stem cuttings or vegetative growth.

- Seeds germinate readily under warm, moist conditions and do not require special pre-treatment.
- Optimal germination occurs within 7–10 days post-sowing, and seedlings establish quickly [37].

3. Cultivation Practices

- **Land Preparation:** Fields are tilled to create a fine seedbed. Organic compost or well-rotted manure may be added to enrich the soil.
- **Sowing:** Seeds are broadcasted or line-sown at 15–20 cm spacing.
- **Watering:** Regular irrigation is necessary during dry spells, especially during the seedling and flowering stages.
- **Weeding:** Manual weeding is advised during the early growth stages to avoid competition.

4. Harvesting

- **Timing:** The plant is typically harvested **6–8 weeks** after sowing when it reaches optimal phytochemical maturity. Harvest time may vary depending on the intended use (e.g., leaves for flavonoids, roots for alkaloids) [38].
- **Technique:** Aerial parts are cut manually using sickles or pruners. For root-based extraction, the entire plant may be uprooted and washed.
- **Post-harvest Handling:** Plant material is cleaned and shade-dried to preserve active compounds. Drying under direct sunlight is avoided to prevent degradation of sensitive phytoconstituents like flavonoids and phenolics [39].

5. Cultivation Potential and Sustainability



- *S. nodiflora* is considered a **low-maintenance, weed-like species**, making it suitable for **sustainable, organic, and medicinal farming systems**.
- It grows rapidly with minimal input, and its resistance to pests and diseases makes it eco-friendly.
- Due to its rapid naturalization and invasiveness, cultivation should be managed to avoid uncontrolled spread [40].

Table No 03 - Summary of Pharmacological Activities and Experimental Models of *Synedrella nodiflora*

Pharmacological Activity	Plant Part	Extract / Isolate	Dose / Route	Bioactive Dose	Positive Control	Negative Control	Animals / Cell Lines	Experimental Model & Parameters	Mechanism of Action	Inference	Ref.
Anticonvulsant (CNS)	Leaves	Ethanol extract	100–400 mg/kg, oral	400 mg/kg	Diazepam (2 mg/kg)	Saline	Swiss albino mice	PTZ-induced seizure model; onset & duration measured	GABA-A receptor modulation	Significant protection in a dose-dependent manner	[41]
Anti-inflammatory	Whole plant	Methanol extract	200 mg/kg, oral	200 mg/kg	Diclofenac (10 mg/kg)	Vehicle only	Wistar rats	Carrageenan-induced paw edema; % edema inhibition	Inhibition of prostaglandin synthesis	Notable anti-inflammatory effect similar to NSAIDs	[42]
Antioxidant	Leaves	Methanol, aqueous	10–200 µg/mL (in vitro)	50 µg/mL	Ascorbic acid	—	DPPH, ABTS, FRAP assays	Free radical scavenging; IC ₅₀ values calculated	Electron donation, ROS quenching	Strong antioxidant potential in both assays	[43]
Antimicrobial	Leaves	Ethanol, methanol	100–500 µg/mL	250 µg/mL	Ciprofloxacin (10 µg)	DMSO	<i>E. coli</i> , <i>S. aureus</i> , <i>Candida</i> spp.	Disc diffusion, MIC, MBC tests	Membrane disruption, enzyme inhibition	Broad-spectrum antimicrobial action observed	[44]
Antidiabetic	Whole plant	Ethanol extract	250 mg/kg, oral × 14 days	250 mg/kg	Glibenclamide (5 mg)	Vehicle	Alloxan-induced diabetic rats	FBG, OGTT, serum insulin, pancreatic histology	β-cell protection, insulin modulation	Significant reduction in blood glucose and restoration of insulin	[45]
Cytotoxicity (anticancer)	Leaves	Methanol extract	25–100 µg/mL (in vitro)	60 µg/mL	Doxorubicin	Untreated cells	HeLa, MCF-7 cell lines	MTT assay, apoptosis markers	Induction of apoptosis, mitochondrial disruption	Dose-dependent cytotoxicity on cancer cells	[46]
Wound healing	Leaves	Ethanol extract in gel	Topical 5% gel, once daily	5% extract	Povidone-iodine	Blank gel	Excision wound in rats	Wound contraction %, epithelialization time, histopathology	Collagen synthesis, angiogenesis stimulation	Enhanced wound closure and re-epithelialization	[47]

Anti-inflammatory (Enzyme)	Leaves	Ethanol extract	50–200 µg/mL (in vitro)	100 µg/mL	Indomethacin	None	COX, LOX enzyme assay kits	Inhibition of COX-2 and 5-LOX activities	Enzyme-targeted anti-inflammatory action	Effective inhibition of inflammatory enzymes	[48]
Pharmacological Activity	Plant Part	Extract / Isolate	Dose / Route	Bioactive Dose	Positive Control	Negative Control	Animals / Cell Lines	Experimental Model & Parameters	Mechanism of Action	Inference	Ref.
Analgesic	Leaves	Aqueous extract	100–400 mg/kg, oral	400 mg/kg	Diclofenac (10 mg/kg)	Saline	Swiss albino mice	Acetic acid-induced writhing test	Peripheral analgesia, prostaglandin inhibition	Dose-dependent reduction in pain behaviors	[49]
Antipyretic	Leaves	Methanol extract	300 mg/kg, oral	300 mg/kg	Paracetamol (150 mg/kg)	Vehicle	Wistar rats	Yeast-induced pyrexia model	Thermoregulation via PGE ₂ suppression	Significant reduction in body temperature over 5 hrs.	[50]
Enzyme Inhibition (in vitro)	Leaves	Ethanol extract	25–250 µg/mL	100 µg/mL	Acarbose	Control buffer	α -Amylase and α -Glucosidase enzymes	Spectrophotometric substrate inhibition assays	Enzyme binding and inhibition	Strong inhibition of carbohydrate metabolism enzymes	[51]
Hepatoprotective	Whole plant	Hydroalcoholic extract	200 mg/kg, oral $\times$ 7 days	200 mg/kg	Silymarin (100 mg/kg)	CMC solution	Rats (Paracetamol-induced hepatotoxicity)	AST, ALT, bilirubin, histopathology	Antioxidant and membrane stabilizing effect	Effective hepatoprotection; normalization of liver markers	[52]
Antidiarrheal	Whole plant	Ethanol extract	200–400 mg/kg, oral	400 mg/kg	Loperamide	Saline	Swiss mice	Castor oil-induced diarrhea; frequency and onset of stooling	Inhibition of intestinal motility and secretion	Significant antidiarrheal activity at higher dose	[53]
Antifungal	Leaves	Ethanol extract	100–400 µg/mL (in vitro)	400 µg/mL	Ketoconazole	DMSO	<i>Candida albicans</i> , <i>A. niger</i>	Agar well diffusion, MIC determination	Cell wall inhibition	Inhibition zones observed against common fungal pathogens	[54]
Muscle Relaxant (CNS)	Leaves	Methanol extract	250 mg/kg, oral	250 mg/kg	Diazepam (2 mg/kg)	Saline	Albino mice	Rota-rod and chimney test for motor coordination	CNS depression via GABAergic pathway	Reduction in motor activity and coordination	[55]

Extensive in vivo and in vitro studies demonstrate that *Synedrella nodiflora* exhibits a broad spectrum of pharmacological activities, validating its traditional medicinal uses across systems like Ayurveda, Unani, and folk medicine.

1. Central Nervous System (CNS) Effects

Anticonvulsant, sedative, and muscle relaxant activities were confirmed in rodent models using ethanolic and methanolic extracts. The plant modulated GABAergic transmission and motor coordination, suggesting potential for antiepileptic and anxiolytic drug development.[41] [55]

2. Anti-inflammatory and Analgesic Actions

Carrageenan-induced paw edema and acetic acid writhing tests revealed dose-dependent anti-inflammatory and analgesic effects, comparable to diclofenac. These effects are likely due to

prostaglandin synthesis inhibition and enzyme (COX, LOX) suppression. [42][48][49]

3. Wound Healing & Hepatoprotection

Topical gel formulations accelerated wound contraction and re-epithelialization, supporting traditional wound care use. In hepatotoxic models, extracts showed significant protection against liver damage, normalizing ALT/AST and liver histology.[47][52]

4. Antioxidant & Cytotoxic Properties

Strong free radical scavenging activity was observed in DPPH, ABTS assays, with IC₅₀ values close to standard antioxidants. Extracts induced cytotoxicity in HeLa and MCF-7 cell lines, indicating potential for anticancer applications.[43][46]

5. Antimicrobial and Antifungal Activities



Extracts inhibited growth of bacteria (*E. coli*, *S. aureus*) and fungi (*Candida albicans*), suggesting broad-spectrum antimicrobial potential. Likely mechanisms include cell membrane disruption and enzyme inhibition. [44][54]

6. Antidiabetic and Enzyme Inhibition

Both in vivo (alloxan-induced models) and in vitro studies demonstrated hypoglycemic activity and inhibition of α -amylase/ α -glucosidase, indicating utility in managing diabetes. [45][51]

7. Gastrointestinal Benefits

The plant showed antidiarrheal activity by delaying the onset and reducing the frequency of defecation, suggesting inhibition of intestinal motility and secretion.[53]

8. Antipyretic Effects

Methanolic extract significantly reduced yeast-induced pyrexia, further confirming its traditional use in fevers.[50]

Although *Synedrella nodiflora* (L.) Gaertn. is not currently associated with any widely recognized granted patents, recent pharmacological and agricultural studies indicate diverse applications with significant commercial and societal potential.

1. Human Health Applications

Emerging evidence highlights the plant's usefulness in managing several pathological conditions. Hydro-ethanolic extracts of the whole plant exhibited analgesic effects in paclitaxel-induced neuropathic pain models in rats, with activity comparable to pregabalin, a standard antineuropathic agent [56]. Another study demonstrated that methanolic extracts of *S. nodiflora* exert potent anti-inflammatory effects by downregulating COX-2, iNOS, PGE₂, TNF- α ,

and other inflammatory mediators in LPS-stimulated RAW264.7 macrophage cells [57]. These effects were linked to the inhibition of Syk/Akt signaling pathways, underlining its mechanistic relevance in inflammation control. Behavioral assessments in rodent models also reveal antidepressant and antipsychotic effects, possibly mediated through serotonergic and noradrenergic receptor modulation [58]. These findings suggest the plant could serve as a lead for developing herbal-based neuropsychiatric therapeutics.

2. Applications in Agriculture and Animal Health

In the agricultural domain, the plant has shown allelopathic effects in seed germination bioassays. Aqueous leaf leachates at lower concentrations enhanced seed germination and early growth of radish and mustard, whereas higher concentrations suppressed it. This biphasic response suggests the feasibility of using *S. nodiflora* in the development of bioherbicides or natural plant growth regulators [59]. Additionally, reports from Papua New Guinea and parts of West Africa describe the plant's use as livestock fodder, particularly for pigs, goats, and rabbits, indicating its nutritional value and acceptability in animal feed systems [60].

3. Material and Insecticidal Utility

The essential oil components of *S. nodiflora*, notably β -caryophyllene, α -pinene, and other terpenoids, possess documented antimicrobial and insecticidal properties [61]. These findings present a case for further exploration of its potential in natural pesticide formulations, insect-repelling preparations, or botanical preservatives for agricultural produce.

4. Green Energy and Biomass Potential



Although no direct studies currently evaluate *S. nodiflora* for biofuel or biomass conversion, the plant's fast growth, widespread distribution, and resilience to varying agro-climatic conditions make it a candidate for future research in green energy. Its robust biomass accumulation hints at potential utility in bio-composting, biochar, or biogas systems, especially within sustainable farming or circular bioeconomy models [62].

Marketed Formulations of *Synedrella nodiflora* in Traditional Medicine Systems

Synedrella nodiflora (L.) Gaertn. is widely recognized for its therapeutic properties in traditional systems such as Ayurveda, Unani, Siddha, Naturopathy, and other herbal practices. Several marketed formulations incorporate its extracts or powders either as a primary or adjunct ingredient, targeting diverse ailments.

1. Ayurvedic Formulations

In Ayurveda, *S. nodiflora* is valued primarily for its anti-inflammatory, analgesic, and antipyretic properties. It is included in polyherbal formulations designed to treat:

- **Rheumatism and arthritis,**
- **Fever and inflammation,**
- **Skin disorders** such as eczema and psoriasis.

Examples of marketed Ayurvedic products containing *S. nodiflora* include “Jwarahara Kwatha” (anti-fever decoction) and “Shothahara Churna” (anti-inflammatory powder) where its leaf powder or extract contributes to the therapeutic effect [63][64].

2. Unani and Siddha Formulations

In Unani medicine, *S. nodiflora* finds use in formulations targeting neurological and gastrointestinal disorders. It is often combined

with other herbs in “Majoon” (herbal jams) and “Joshanda” (herbal teas) to alleviate convulsions, digestive disturbances, and respiratory ailments [65]. Similarly, Siddha practitioners utilize *S. nodiflora* in external applications such as medicated oils and ointments for treating wounds and inflammatory skin conditions [66].

3. Naturopathic and Herbal Products

In the naturopathy and herbal product sector, *Synedrella nodiflora* is increasingly being formulated into:

- **Herbal teas and infusions** for general health enhancement and detoxification,
- **Topical gels and creams** aimed at wound healing and pain relief,
- **Dietary supplements** targeting antioxidant support and metabolic balance.

Several commercially available herbal preparations blend *S. nodiflora* with other botanicals to enhance efficacy and broaden therapeutic coverage [67].

4. Commercial Availability and Regulatory Status

While *Synedrella nodiflora* is widely used in traditional medicine, isolated standardized extracts are less common in mainstream commercial products. Most marketed formulations use crude leaf powders or hydroalcoholic extracts. Regulatory approval varies by country; however, due to its extensive traditional use and growing pharmacological validation, *S. nodiflora* is increasingly accepted in AYUSH-compliant herbal formulations in India and other South Asian countries [68].

Toxicological Studies and Safety Profile of *Synedrella nodiflora*



Evaluating the safety and toxicological profile of *Synedrella nodiflora* is essential for its therapeutic application and commercial development. Several in vivo and in vitro studies have assessed its acute and subchronic toxicity, genotoxicity, and cytotoxicity to establish safe dosage parameters.

1. Acute Toxicity

Acute oral toxicity studies conducted on rodents revealed that aqueous and hydroalcoholic extracts of *S. nodiflora* are relatively safe at doses up to 2000 mg/kg body weight, with no observed mortality or significant behavioral changes [69][70]. These studies conform to OECD guidelines 423 and 425, indicating a high median lethal dose (LD₅₀), suggesting the extracts are practically non-toxic in acute exposure.

2. Subchronic and Chronic Toxicity

Subchronic toxicity studies with repeated administration of *S. nodiflora* extracts over 28 days at doses ranging from 250 to 1000 mg/kg showed no significant alterations in hematological, biochemical, or histopathological parameters in liver, kidney, or heart tissues [71]. Minor reversible changes in liver enzyme activities were noted at higher doses but were within normal physiological limits, indicating low systemic toxicity.

3. Genotoxicity and Cytotoxicity

Genotoxicity evaluation through micronucleus and comet assays demonstrated no DNA damage or chromosomal aberrations induced by *S. nodiflora* extracts at therapeutic concentrations [72]. Cytotoxicity assays using various human cell lines reported low cytotoxic effects, supporting its safety for topical and systemic use [73].

4. Safety in Traditional Use

Historically, *S. nodiflora* has been consumed in traditional medicine without reports of significant adverse effects, corroborating experimental toxicology findings. However, caution is advised in pregnant or lactating women due to lack of comprehensive reproductive toxicity studies [74].

5. Recommendations for Further Studies

While current evidence supports a favorable safety profile, further comprehensive studies are needed to evaluate:

- **Long-term toxicity and carcinogenicity,**
- **Reproductive and developmental toxicity,**
- **Potential herb-drug interactions-**Especially considering its use in polyherbal formulations.

Future Prospective Scope for Study of *Synedrella nodiflora*

Despite the growing body of research elucidating the pharmacognostic, phytochemical, and pharmacological properties of *Synedrella nodiflora*, several areas remain underexplored, offering promising avenues for future scientific investigation and application development.

1. Advanced Phytochemical Profiling and Standardization

While preliminary studies have identified key phytochemical classes such as flavonoids, terpenoids, and alkaloids, comprehensive metabolomic and chemoprofiling using advanced techniques like LC-MS/MS, NMR spectroscopy, and metabolomics approaches are warranted. This would facilitate:

- Identification of novel bioactive compounds,
- Quantitative standardization of extracts for reproducible therapeutic outcomes, and
- Development of quality control markers for regulatory compliance [75].



2. Mechanistic and Molecular Studies

Although some pharmacological mechanisms such as anti-inflammatory and neuroprotective pathways have been proposed, detailed molecular investigations are required to:

- Elucidate precise signaling pathways modulated by *S. nodiflora* constituents,
- Understand receptor-ligand interactions,
- Explore epigenetic and transcriptomic effects,
- Assess synergistic or antagonistic interactions within polyherbal formulations [76].

3. Clinical and Toxicological Research

Translation of preclinical findings into clinical applications remains limited. Future research should emphasize:

- Rigorous clinical trials evaluating efficacy and safety in humans,
- Pharmacokinetic and bioavailability studies,
- Long-term toxicity, reproductive toxicity, and herb-drug interaction assessments to establish comprehensive safety profiles [77].

4. Novel Formulation Development

Given the plant's multipurpose bioactivity, there is potential for innovation in:

- Nanotechnology-based delivery systems (e.g., nanoparticles, liposomes) to enhance bioavailability,
- Transdermal and sustained-release formulations for targeted therapy,
- Integration into functional foods, nutraceuticals, and cosmeceuticals [78].

5. Agricultural and Environmental Applications

Further exploration of the allelopathic, insecticidal, and antimicrobial properties can support:

- Development of eco-friendly bioherbicides and biopesticides,
- Use in sustainable agriculture as green manure or fodder crops,
- Potential in phytoremediation and biomass-based renewable energy production [79].

6. Intellectual Property and Commercialization

As research advances, protection of novel extracts, compounds, and formulations via patents is essential. Collaborative efforts between academia and industry could accelerate:

- Commercial development of standardized herbal products,
- Establishment of regulatory guidelines ensuring safety, efficacy, and quality [80].

CONCLUSION

Synedrella nodiflora is a versatile medicinal plant extensively used in various traditional medicine systems for its broad therapeutic potential. The presence of diverse bioactive compounds such as flavonoids, alkaloids, terpenoids, and phenolic compounds underpins its pharmacological activities including anti-inflammatory, antioxidant, antimicrobial, and neuroprotective effects. Toxicological studies indicate a favorable safety profile, supporting its traditional use and encouraging further clinical evaluation. Beyond its medicinal applications, *S. nodiflora* also shows promise in agricultural and environmental sectors, offering eco-friendly alternatives as bioherbicides and biomass sources. Future research focusing on detailed phytochemical standardization, mechanistic insights, clinical validation, and novel formulation development will be crucial to fully

harness its therapeutic and commercial potential. Overall, *Synedrella nodiflora* represents a valuable natural resource with significant prospects for contributing to healthcare and sustainable agriculture, meriting continued multidisciplinary research and development.

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