

A Review on the Pharmacognostical, Phytochemical, Pharmacological Aspects of *Cleome gynandra* L.

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Abstract: *Cleome gynandra* L., commonly known as spider plant or “Nalvelai,” is a nutritionally and medicinally important leafy vegetable belonging to the family Capparaceae. It is widely distributed throughout tropical and subtropical regions and is traditionally used for managing various health conditions, including gastrointestinal disorders, inflammation, epilepsy, and parasitic infections. The plant is also consumed as a vegetable owing to its nutritional content and antioxidant potential. Phytochemical investigations have identified diverse bioactive constituents, including flavonoids, phenolic compounds, alkaloids, terpenoids, saponins, vitamins, and minerals, which may contribute to its therapeutic properties. Several experimental studies have reported antioxidant, antidiabetic, antimicrobial, anti-inflammatory, analgesic, immunomodulatory, hepatoprotective, and anticancer activities. This review summarizes the botanical, cultivation, pharmacognostical, phytochemical, nutritional, traditional, and pharmacological aspects of *C. gynandra* L., with particular emphasis on its antioxidant and antidiabetic potential. The review also identifies important research gaps, including the need for standardized extracts, isolation of active constituents, mechanistic studies, toxicity assessment, bioavailability evaluation, and advanced in-silico and in-vivo investigations. Overall, *C. gynandra* represents a promising source of bioactive compounds with potential applications in natural-product-based therapeutic research.

Keywords: *Cleome gynandra* L.; Pharmacognosy; Morphology; Cultivation; Phytochemicals; Ethnomedicinal Uses; Antioxidant Activity; Antidiabetic Activity; Anticancer activity; Pharmacological potential; In-Silico Studies.

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I. INTRODUCTION

Natural products remain an important source of bioactive compounds for modern drug discovery and development, with a substantial proportion of clinically used medicines being derived directly or indirectly from natural sources(1,2). Plant-derived compounds may be used in their natural form or modified synthetically or semi-synthetically to improve their therapeutic properties(3). Herbal medicines have long contributed to healthcare and continue to be widely used, particularly in traditional medical systems worldwide(4,5). *Cleome gynandra* L., belonging to the family Capparaceae, is a medicinally important plant commonly known as “Nalvelai” or “Taivelai” in Tamil(6). It is an erect, branched annual or short-lived perennial herb widely distributed in tropical and subtropical regions. In India, it commonly occurs in agricultural fields, roadsides, wastelands, and open grasslands, while its natural distribution also extends extensively across tropical and subtropical Africa(7–11). The plant generally grows to about 25–60 cm

in height and possesses a branched, glandular-haired stem. Its leaves are alternate and palmately compound, usually consisting of three to five obovate leaflets, while the flowers are arranged in elongated terminal inflorescences and are typically white, pinkish, or rose-coloured(11,12). *C. gynandra* has a long history of traditional medicinal use for conditions including food poisoning, rheumatic and inflammatory disorders, toothache, headache, bacterial infections, snake-bite-related conditions, and skin disorders(13–15). Phytochemical and pharmacological investigations have further reported antioxidant, antimicrobial, and anti-inflammatory activities, supporting its potential relevance in wound management and other therapeutic applications(16,17). The plant has also been documented in Ayurvedic literature and reported as an ingredient of formulations such as Narayana Churna, with traditional applications including anthelmintic, gastrointestinal, ear-related, and pruritic conditions(18). Considerable morphological variation has been observed among *C. gynandra* accessions, particularly in plant height,

pod length, leaf characteristics, flower colour, gynophore and filament morphology, and flowering or maturity time, highlighting its importance for germplasm characterization and crop-improvement studies(19). In addition to its medicinal value, the plant is consumed as a leafy vegetable in parts of Thailand and Malaysia, where traditional fermented

preparations such as “phaksian dong” and “jerukmaman” are prepared from its leaves(8). The species is readily propagated by seeds, particularly during the rainy season, and is valued by some communities as a low-maintenance and nutritionally useful leafy crop despite often being regarded as an agricultural weed(20).

➤ *Plant Profile:*⁽⁷⁾



Fig 1 *Cleome Gynandra* L.

➤ *Taxonomical Profile:*⁽²¹⁾

- Kingdom - Plantae
- Subkingdom -Tracheobionta (Vascular plants).
- Super division - Spermatophyta (Seed plants).
- Division/Phylum -Magnoliophyta (Flowering plants/Angiosperms).
- Class - Magnoliopsida (Dicotyledons).
- Subclass - Dilleniidae.
- Order - Brassicales.
- Family- Cleomaceae
- Subfamily - Capparaceae
- Genus - Cleome.
- SubGenus - Gynandropsis
- Species - *Cleome gynandra* L.
- Synonyms - *Gynandropsis gynandra*, *Cleome Africana*.
- Common Names - Spider plant.

➤ *Vernaculars: (Vernacular Names in India)*⁽⁸⁾:

- Sanskrit: Pasugandhi, Ajagandha
- Assamese: Bhutmulla
- Bengali: Hurhuria, Shulte
- English: Dog Mustard
- Gujarat: Talvani, Dhelitalavan
- Hindi: Hulhul, Hurhur, Kavalia

- Kannada: Naram bele Soppu, Nayeetulasi
- Kashmiri: Gandi Buti
- Malayalam: Atunari vela
- Marathi: Tilvan, Bhatvan, Mabli, Tilavana, Tilvant
- Oriya: Anasoria, anasoria, Hulhulia
- Punjabi: Bugra
- Tamil: Nal valai, Nal velai
- Telugu: Vaminta, Vayinta

II. ORIGIN AND DISTRIBUTION

Cleome gynandra L. is believed to have originated in Africa and is now widely distributed throughout tropical and subtropical regions of the world(22). In India, it is commonly found in warm tropical and subtropical regions, particularly in states such as Tamil Nadu, Andhra Pradesh, Maharashtra, Uttar Pradesh, and West Bengal. The species frequently occurs in wastelands, roadsides, agricultural fields, and other disturbed habitats, especially during the rainy season when adequate moisture favours its growth and regeneration(23,24).

In southern Africa, *C. gynandra* is widely distributed across regions including Limpopo, North-West, Gauteng, Mpumalanga, KwaZulu-Natal, Free State, Northern Cape, and Namibia. Semi-cultivation in certain areas may also have contributed to its persistence and wider distribution(25). The

species has subsequently become established in several tropical and subtropical regions outside Africa, reflecting its ability to tolerate and adapt to diverse environmental conditions(26). It generally grows well under warm climatic conditions and in well-drained soils such as sandy loam(24). *C. gynandra* should be distinguished from the closely related ornamental species *Cleome hassleriana*, which is native to tropical America and is commonly cultivated for its attractive pink or white flowers(25).

➤ Cultivation

Although *Cleome gynandra* L. commonly occurs as a wild weed, it is also cultivated and utilized as a leafy vegetable and medicinal plant in several regions. Large-scale commercial cultivation is limited, and leaves are often collected from naturally occurring populations. However, suitable agronomic practices have been investigated to improve its growth and productivity(27).

- **Soil Requirements**

C. gynandra grows well in deep, fertile, well-drained soils with adequate organic matter. Loose soils with good moisture retention and a pH of approximately 5.5–7.0 are generally suitable for its growth and establishment(27).

- **Propagation and Sowing**

The plant is mainly propagated by seeds. Proper seedbed preparation and shallow sowing are important because of the small seed size. Seeds may be broadcast or sown in rows, with approximately 30 cm spacing between rows and a sowing depth of about 1 cm, depending on local conditions(27).

- **Nutrient Management**

Adequate nutrient supply, particularly nitrogen, promotes vegetative growth and leaf biomass production. Appropriate nitrogen management can increase leaf yield and size and may delay flowering, thereby extending the vegetative and harvesting period(27).

- **Water Management**

Adequate soil moisture is essential for optimum vegetative growth and biomass production. Irrigation may be provided during periods of insufficient rainfall, with frequency and quantity adjusted according to soil type, water-holding capacity, climatic conditions, and crop requirements(27).

- **Harvesting**

Leaves may be harvested either by uprooting the entire plant or by repeated cutting of the upper shoots. Repeated harvesting encourages lateral branching and the production of young leaves, while potentially delaying flowering and extending the vegetative phase. This method therefore permits multiple harvests and may improve overall leaf productivity (27).

➤ Morphology

- **Macroscopic Characteristics**

Cleome gynandra L. is an erect, extensively branched herb that generally grows to about 25–60 cm in height. Older stems may become slightly woody, and the plant is characterized by a distinctive strong odour. The stem, leaves, flowers, fruits, and seeds possess characteristic features useful for preliminary identification.

- **Stem**

The stem is branched, longitudinally striated, and covered with glandular hairs, giving it a granular and sometimes sticky appearance. These glandular and striated characteristics are important diagnostic features.

- **Leaves**

The leaves are alternate and palmately compound, usually consisting of three to five leaflets. The petiole is relatively long and bears glandular hairs. The leaflets are generally obovate, smooth or glandular, and may possess scattered multicellular hairs, particularly along the principal veins(8).

- **Inflorescence**

The flowers are arranged in elongated terminal inflorescences. The flowering axis continues to elongate during fruit development, and the individual flowers are borne on slender, glandular-pubescent pedicels of approximately 1–2 cm in length(27).

- **Flower**

The flowers are generally asymmetrical and consist of four glandular sepals and four spatulate petals. The petals are typically white, pink, or lilac, with a narrow base and rounded apex. Six stamens are present, with the filaments partly united near the base and free towards the upper region; they are often purplish in colour. The combination of floral characters, particularly the gynophore and filaments, is useful in species characterization(27).

- **Fruit**

The fruit is an elongated, tapered, fusiform capsule that may reach approximately 10 cm in length. The capsule surface may be glandular or glabrous depending on the developmental stage and individual variation, and the mature fruit contains numerous seeds(27).

- **Seed**

The seeds are small, rounded to discoid, and approximately 1.5 mm in diameter. They are generally brown to black and possess a wrinkled or reticulate seed coat. These characteristic seed features are useful for species identification(27).

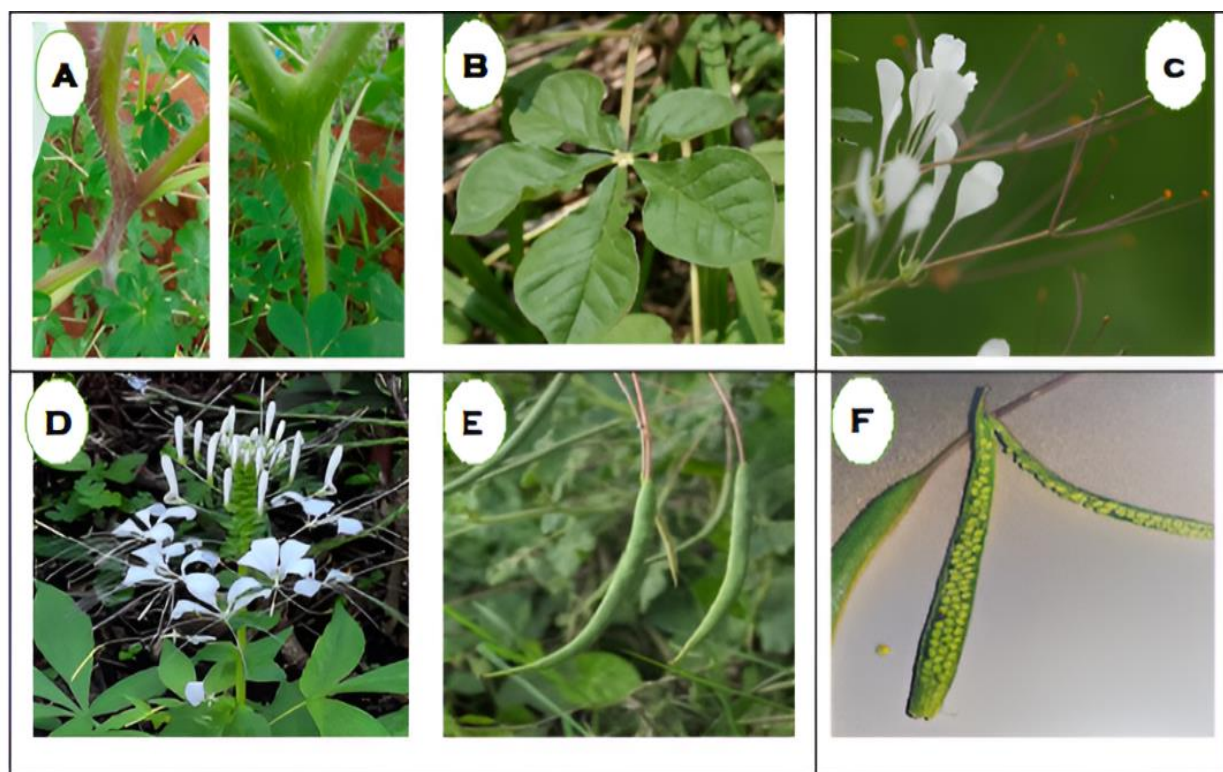


Fig 2 Morphological Characters of Stem(A), Leaf (B), Inflorescence(C), Flowers(D), Fruits(E) and Seeds(F).

➤ Microscopy

• Transverse Section of Stem (T.S.)

The transverse section of the stem shows a single-layered epidermis of rounded cells covered by a prominent cuticle. The epidermis bears various trichomes, including multi-seriate, spine-like non-glandular trichomes, long-stalked uni-, bi-, tri-, and multi-seriate trichomes, and short-stalked capitate glandular trichomes. The trichome bases are composed of several cells. Beneath the epidermis, a 2–3-layered zone of thick-walled, polygonal collenchymatous cells is present(28).

• Transverse Section of Leaf (T.S.)

The leaf shows a distinct, broad and thick midrib with a comparatively thick lamina. The epidermis consists of compact, rounded cells covered externally by a well-developed cuticle. The midrib bears prominent multi-seriate, spine-like non-glandular trichomes, along with unicellular elongated non-glandular and short-stalked bi- and tri-seriate capitate glandular trichomes. A 2-layered region of thick-walled collenchymatous cells occurs beneath the epidermis, particularly around the midrib(28).

• Transverse Section of Seed (T.S.)

The seed section consists of distinct epidermal, sub-epidermal, parenchymatous, integumentary, and endosperm regions. The epidermis is mainly composed of vertically elongated, thin-walled cells showing variation in size and shape across different regions. In some portions, the epidermal tissue may occur as a 2–3-layered structure. These anatomical features provide useful microscopic characters for the identification of the seed(28).

III. POWDER MICROSCOPIC STUDIES

The powdered drug is dark brown and slightly oily in appearance. Microscopic examination shows fragments of thin-walled, polygonal testa epidermal cells and groups of reddish-brown, non-lignified stone-like cells. Oval, rounded, and irregularly shaped protein bodies are also present. Starch grains, calcium oxalate druses, fat and fatty-oil globules, and elongated cortical fibres with thick, pitted walls may be observed in different tissue fragments. These features provide useful diagnostic characters for identification of the powdered drug(18,28).

➤ Epidermis in Surface View

The epidermal cells associated with the veins are large, predominantly axial, and generally rectangular to rhomboidal with thick, relatively straight walls. Intercostal epidermal cells are more variable in shape and possess thin, slightly to markedly undulated walls. Three principal types of glandular trichomes—uniseriate clavate, multiseriate spherical, and multiseriate clavate hairs—are observed in both costal and intercostal regions. Occasional shaggy glandular hairs may also occur, particularly in intercostal areas and along vein margins(29).

Stomata occur on both the adaxial and abaxial surfaces and are generally sub-spherical to elliptical. Anomocytic, anisocytic, and tetracytic stomata are present, with the tetracytic type being predominant. Occasional abnormal stomata, including contiguous, shrivelled, and incompletely developed stomata, may also be observed. The stomata are approximately 18.21–20.5 μm in breadth, while the reported stomatal indices are about 21.57 and 20.9 for the abaxial and adaxial surfaces, respectively(29).

The adaxial epidermis generally possesses straighter cell walls, whereas the abaxial epidermis shows greater wall undulation. Distinct rhomboidal to broadly rectangular vein-islets and vein terminations are visible, with mean values of approximately 91.76 and 116 per mm², respectively(29). The

characteristic combination of epidermal cell patterns, trichome types, stomatal characteristics, and vein-islet features provides valuable pharmacognostical parameters for the authentication and standardization of *Cleome gynandra* L.(29).

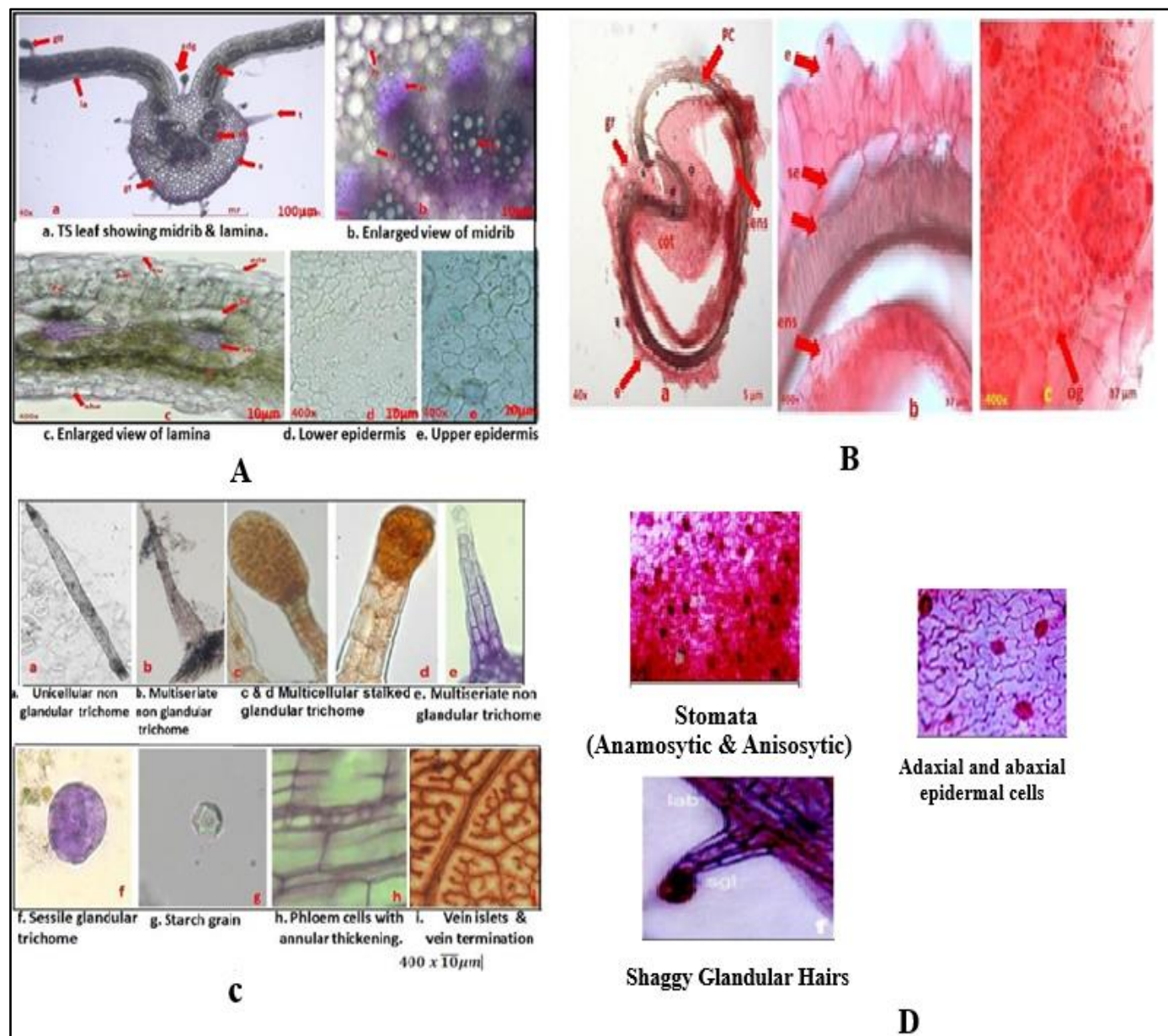
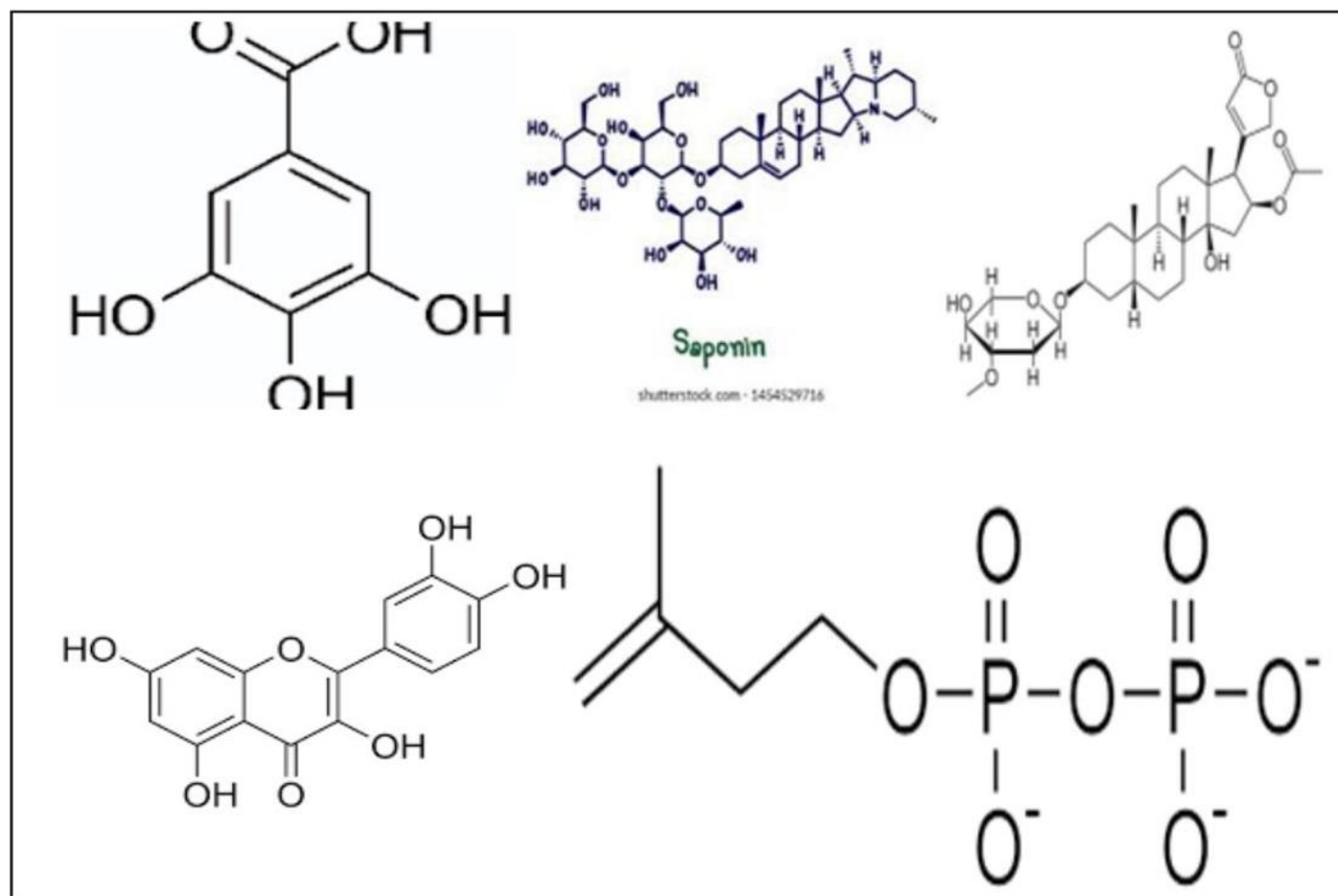


Fig 3 Microscopic Characters of *Cleome gynandra* L. (Leaf(A), Seeds(B), Powder Microscopy(C), Epidermal Cells(D))

➤ Phytoconstituents

The therapeutic relevance of *Cleome gynandra* L. is considered to be associated, at least in part, with the diverse range of nutritional and bioactive constituents present in the plant. Many of the compounds responsible for the reported biological activities of medicinal plants belong to the group of secondary metabolites, which are synthesized through various metabolic pathways within plant tissues. Preliminary phytochemical investigations of *C. gynandra* have demonstrated the presence of several classes of secondary metabolites, including saponins, flavonoids, tannins, alkaloids, cardiac glycosides, terpenoids, and polyphenolic compounds(30).

In addition to these secondary metabolites, *C. gynandra* has been reported to contain other biologically and nutritionally relevant constituents, such as steroids, polysaccharides, and fatty acids. The plant also provides important nutritional compounds, including vitamin C and β -carotene. The combined occurrence of these phytochemical and nutritional constituents may contribute to the antioxidant, metabolic, anti-inflammatory, antimicrobial, and other pharmacological properties reported for the species. Therefore, the diverse phytochemical composition of *C. gynandra* supports its traditional medicinal significance and highlights its potential as a source of bioactive molecules for further pharmacological and therapeutic investigations(30).

Fig 4 Phytoconstituents of *Cleome gynandra* L.

➤ Nutritional Composition

Several investigations have evaluated the nutritional characteristics of fresh leaves of *Cleome gynandra* L. (**Table 1**). The reported moisture content of the leaves ranges from approximately 81.8 to 89.6%, while the pH has been reported to be around 5.8. The nutritional composition of the plant is not necessarily constant and may be influenced by several factors, including soil fertility, environmental conditions, genetic variation, stage of plant development, and agricultural or production practices(31).

Table 1 Nutritional composition of *Cleome gynandra* L. leaves

Nutrient	Reported range (% or mg/100 g edible portion)
Crude protein (%)	3.1–7.7
Crude fibre (%)	1.3–1.4
Carbohydrates (%)	4.4–6.4
Ether extract (%)	0.4–0.9
Total ash (%)	2.1–3.0
Potassium (mg)	410
Calcium (mg)	213–434
Magnesium (mg)	86
Sodium (mg)	33.6
Phosphorus (mg)	12
Iron (mg)	1–11
Zinc (mg)	0.76
Copper (mg)	0.46
β-Carotene (mg)	6.7–18.9
Ascorbic acid (mg)	127–484
Oxalate (mg)	8.8
Total phenolics (mg)	520–910

The lipid fraction of *C. gynandra* leaves is characterized by a high degree of unsaturation. Among the fatty acids identified, linoleic acid represents the major component and accounts for approximately 59% of the total fatty-acid content. The principal fatty acids reported from the leaves include palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, arachidic acid, and eicosenoic acid. The relatively high iodine and saponification values, reported as approximately 123 and 192, respectively, further indicate the predominance of unsaturated fatty acids in the lipid fraction. Differences among cultivars have been observed in the

relative proportions of individual fatty acids, with cultivated forms generally showing a lower proportion of stearic acid compared with palmitic acid(31).

The amino acid composition of the defatted leaf meal has also been investigated. Glutamic acid was reported to occur in the highest proportion, followed by arginine, aspartic acid, lysine, tyrosine, and histidine. The overall amino acid profile demonstrates similarities to those reported for certain leguminous oilseed crops, indicating the potential nutritional significance of *C. gynandra* leaves (Table 2)(25).

Table 2 Amino Acid Profile Reported for Selected *Cleome gynandra* L. Seeds Collected from Zambia (25)

S. No.	Amino acid
1	Glutamic acid
2	Arginine
3	Aspartic acid
4	Leucine
5	Valine
6	Glycine
7	Proline
8	Phenylalanine
9	Isoleucine
10	Threonine
11	Alanine
12	Serine
13	Lysine
14	Tyrosine
15	Histidine

• Leaves

The leaves of *Cleome gynandra* L. are reported to contain a diverse range of phytochemical and nutritional constituents. Flavonoids such as quercetin, kaempferol, luteolin, and naringenin have been identified, along with other classes of compounds including flavonoid glycosides, tannins, phenolic constituents, saponins, and carotenoids such as β -carotene. The leaves are also considered nutritionally valuable because they provide proteins, amino acids, vitamin C, and essential minerals, particularly calcium, iron, and zinc(24).

• Stem

Phytochemical investigations of the stem have indicated the occurrence of several classes of secondary metabolites. Flavonoids such as rutin and hesperidin have been reported, together with tannins, minor quantities of alkaloids, sterols, and triterpenoid constituents. Among the reported triterpenoids are lupeol and β -amyrin. The combined presence of these constituents may contribute to the antioxidant and anti-inflammatory activities associated with the stem and other parts of the plant(33,34).

• Root

The roots of *C. gynandra* contain several structurally diverse phytoconstituents, including flavonoid glycosides such as naringenin-4-O-galactoside and dihydrokaempferol-4'-O-galactoside. Triterpenoids, particularly lupeol and β -amyrin, have also been reported from the root. The presence

of these bioactive constituents may partly account for the traditional use of the roots in wound management and for reported antidiabetic and anti-inflammatory applications(24,35).

• Bark

Although *C. gynandra* is predominantly herbaceous and does not develop a typical woody bark, the outer stem tissues have been reported to contain several bioactive constituents. These include triterpenoids, phytosterols, phenolic compounds, and saponins. The occurrence of these phytochemical groups may contribute to the reported antimicrobial, protective, and other medicinal properties of the plant(32,35).

➤ Properties and Action According to Ayurvedic Concept⁽¹⁸⁾:

- Rasa: Katu
- Guna: Laghu, Ruksha
- Virya: Sita
- Vipaka: Katu
- Karma : Sulaghni, Dipana, Hrdya, Pittala, Vatahara

➤ *Therapeutic Uses (Ayurvedic)⁽¹⁸⁾:*

- Gulma (Any tumour, lump or diverticulosis),
- Asthila (Prostate enlargement),
- Krmiroga (Worm infection),
- Kandu (Pruritus),
- Karnaroga (Ear diseases).

IV. FOOD AND TRADITIONAL MEDICINAL USES OF *CLEOME GYNANDRA* L. WORLDWIDE(28,31)

Cleome gynandra L. is widely consumed as a leafy vegetable in several African countries, including Nigeria, Malawi, Zimbabwe, Cameroon, Botswana, Namibia, Tanzania, Zambia, South Africa, Ghana, Uganda, and Kenya. In India, tender leaves are commonly cooked as a vegetable and may also be used in sauces and other culinary preparations. In Thailand, the leaves are traditionally fermented and consumed as “pak-sian-dong”(28,31).

In Kenya and other African communities, the leaves are valued for their nutritional and traditional health benefits. They may be consumed cooked, prepared as drinks, or subjected to fermentation or marination in sour milk. Traditional knowledge associates these preparations with benefits such as supporting general health, eyesight, energy, and nutritional well-being. The vegetable is also traditionally included in the diets of pregnant and lactating women in some communities, although beliefs regarding its influence on lactation vary geographically(28,31).

The seeds are an additional source of nutritional value, containing oil rich in polyunsaturated fatty acids. The extracted oil may be obtained by mechanical pressing, while the residual seed cake has a favourable amino acid composition and may be utilized as animal feed. The seeds are also used as feed for birds(28,31).

➤ *Traditional Medicinal Applications*

Different parts of *C. gynandra*, particularly the leaves and seeds, have been used in traditional healthcare systems in various regions. Preparations include fresh leaf juice or sap, crushed leaves, decoctions, infusions, and external applications. Traditionally reported applications include:

- *Pain and headache:*

Fresh leaf sap or crushed leaves may be used for headache and other localized painful conditions.

- *Ear, Eye, and Nasal Disorders:*

Leaf juice has traditionally been applied to the eyes, ears, or nostrils for various complaints.

- *Gastrointestinal Disorders:*

Leaf or root decoctions have been used traditionally for stomach pain, constipation, and intestinal worm infections.

- *Childbirth and Fever:*

Decoctions of the plant, particularly the roots, have traditionally been used to support childbirth and manage fever.

- *Arthritis and Rheumatism:*

Leaf preparations have been traditionally employed for arthritic, rheumatic, and other inflammatory complaints.

- *Topical Applications:*

Bruised or crushed leaves have been applied externally for headache, neuralgia, rheumatism, wounds, and localized pain. Such applications may act as counter-irritants and are generally used cautiously because prolonged contact may cause skin irritation.

- *Regional Applications:*

Traditional uses reported from different regions include the management of dysentery, gonorrhoea, malaria, rheumatoid arthritis, piles, wounds, and tumorous conditions. In India, the plant has also been traditionally used as an anthelmintic and rubefacient(28,31).

The wide range of food and medicinal applications of *C. gynandra* reflects its nutritional and ethnomedicinal importance across different cultures and provides a basis for further pharmacological investigation(28,31).

V. PHARMACOLOGICAL ACTIVITIES

➤ *Anti-Inflammatory and Antinociceptive Activity*

Inflammation and pain are closely related physiological responses involving inflammatory mediators and nociceptive pathways. Experimental models such as the hot-plate and acetic acid-induced writhing tests are commonly used to evaluate central and peripheral antinociceptive effects, respectively. Acetic acid-induced writhing is primarily associated with the peripheral release of inflammatory mediators and subsequent activation of nociceptors.

Aqueous extract of *Gynandropsis pentaphylla* (AEGP) has demonstrated significant antinociceptive activity in both hot-plate and acetic acid-induced writhing models, with responses reported to be comparable to those of a standard analgesic. This activity may be associated with flavonoids such as rutin, quercetin, luteolin, hesperidin, and biflavonoids, as well as tannins, which have been reported to possess analgesic and anti-inflammatory properties. The observed antinociceptive effect may therefore involve both central and peripheral mechanisms.(33,36).

Prostaglandins are important mediators of inflammation and pain, while conventional NSAIDs primarily reduce these responses by inhibiting cyclooxygenase (COX) enzymes and prostaglandin synthesis. Flavonoids and tannins present in *C. gynandra* may contribute to anti-inflammatory activity through modulation of prostaglandin biosynthesis and related inflammatory pathways(33,36). Other phytoconstituents, including alkaloids, terpenoids, and phenolic compounds, may also influence important inflammatory mediators and signalling pathways such as COX, lipoxygenase (LOX),

tumour necrosis factor- α (TNF- α), IL-1 β , IL-6, nitric oxide (NO), and nuclear factor kappa B (NF- κ B)(38).

Although corticosteroids and NSAIDs are effective in the management of inflammatory disorders, prolonged or inappropriate use may result in adverse effects, including gastrointestinal, renal, and cardiovascular complications(37). These limitations have increased interest in plant-derived compounds with potential anti-inflammatory and analgesic properties.

C. gynandra has traditionally been used for painful and inflammatory conditions and has been reported to possess anti-inflammatory, antioxidant, antimicrobial, and analgesic activities. However, further studies are required to identify the active constituents and clarify their molecular mechanisms, dose-response relationships, safety, and potential clinical applications(39).

➤ Free Radical Scavenging and Antioxidant Activities

Free radicals and reactive oxygen species (ROS) play an important role in oxidative stress and are associated with the development and progression of several chronic disorders, including diabetes, rheumatoid arthritis, cardiovascular diseases, neurodegenerative disorders, and cancer(42). Therefore, natural compounds with free-radical-scavenging and antioxidant properties have attracted considerable interest for their potential to reduce oxidative damage.

The antioxidant activity of *Cleome gynandra* L. has been demonstrated in experimental models of oxidative stress. In an adjuvant-induced arthritis model in rats, oral administration of *C. gynandra* leaf extract at 150 mg/kg body weight for 30 days significantly influenced antioxidant-related parameters, including lipid peroxidation, catalase, glutathione peroxidase, reduced glutathione, and superoxide dismutase. Histopathological observations further indicated protective effects against oxidative tissue damage(29,40).

In vitro studies have also demonstrated the antioxidant and free-radical-scavenging potential of *C. gynandra* extracts using ferric-reducing power, ABTS, DPPH, and nitric oxide scavenging assays. These activities have been associated with the presence of phytoconstituents such as phenolics, flavonoids, flavanols, proanthocyanidins, tannins, saponins, and alkaloids(41). The combined action of these constituents may contribute to the neutralization of reactive species and protection against oxidative damage.

Oxidative stress occurs when ROS generation exceeds the capacity of endogenous antioxidant defence systems. Reactive species such as superoxide anions, hydroxyl radicals, and hydrogen peroxide can cause oxidative modification of proteins, lipids, and nucleic acids, thereby contributing to chronic and age-related diseases(42). Antioxidants counteract these effects by donating electrons, scavenging reactive species, or interrupting oxidative chain reactions.

Although synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA)

are widely used, concerns regarding their potential adverse effects have encouraged the search for safer natural antioxidant sources(43).

➤ Anticancer Activity

The anticancer potential of methanolic extract of *Cleome gynandra* L. (MECG) has been investigated in Swiss albino mice bearing Ehrlich Ascites Carcinoma (EAC). Intraperitoneal administration of MECG at 200 and 400 mg/kg body weight significantly reduced tumour volume, viable tumour cell count, and tumour weight, while increasing the survival period of tumour-bearing animals. The extract also improved altered haematological parameters, including erythrocytes, haemoglobin, leukocytes, and lymphocytes, towards normal values. These findings indicate a dose-dependent antitumour effect of *C. gynandra* under the experimental conditions(26,44).

Anticancer agents may act through multiple mechanisms, including inhibition of tumour cell proliferation, induction of apoptosis, modulation of oxidative stress, inhibition of angiogenesis, and regulation of intracellular signalling pathways(45). Phytoconstituents such as flavonoids, alkaloids, terpenoids, tannins, and phenolic compounds have demonstrated potential anticancer effects through mechanisms involving p53 signalling, caspase-mediated apoptosis, NF- κ B modulation, reactive oxygen species regulation, and suppression of abnormal cellular proliferation. The reported antitumour activity of *C. gynandra* therefore supports its potential as a source of bioactive compounds for further anticancer investigation(46).

➤ Immunomodulatory Effects

Cleome gynandra L. has also demonstrated potential immunomodulatory activity in experimental animal models. Aqueous and ethanolic extracts were reported to influence serum IgG and IgM levels, suggesting an effect on humoral immune responses, with the ethanolic extract showing comparatively greater activity at lower doses(47).

Cell-mediated immune responses were evaluated using an SRBC-induced delayed-type hypersensitivity (DTH) model in albino rats. The ethanolic fraction EECG-I of *C. gynandra* produced marked inhibition of the DTH response, with a reported inhibition of 92.74%, indicating significant suppression of cell-mediated immunity(47). These findings suggest that *C. gynandra* may possess immunomodulatory, particularly immunosuppressive, activity and warrant further investigation to clarify its active constituents and underlying mechanisms.

➤ Antidiabetic Activity

Cleome gynandra L. has traditionally been used by tribal communities and traditional practitioners in parts of western Odisha for the management of diabetes. Although its clinical hypoglycaemic efficacy requires further validation, the leaves and roots are traditionally considered beneficial for blood glucose regulation. Its potential antidiabetic activity may be associated with its phenolic, flavonoid, antioxidant, nutritional, and immunomodulatory constituents(48–52).

Diabetic nephropathy is a major complication of prolonged diabetes and is associated with oxidative and inflammatory damage. Antioxidant-rich plant compounds may help attenuate such effects by reducing oxidative stress markers such as malondialdehyde and improving associated biochemical abnormalities. The phenolic and flavonoid constituents of *C. gynandra* may therefore contribute to its reported antidiabetic and protective activities. Minerals and trace elements present in medicinal plants may also support metabolic and glucose-regulatory functions(48–52).

- *Antidiabetic and Antidyslipidemic Effects*

The antidiabetic and lipid-lowering effects of *C. gynandra* have been evaluated in alloxan-induced diabetic rats. Ethanolic extracts and fractions, particularly EECG-I and EECG-II, produced significant reductions in serum glucose and improvements in altered lipid parameters. Treatment also reduced elevated serum SGOT and SGPT levels and increased high-density lipoprotein (HDL) concentrations compared with diabetic control animals. These findings suggest potential antihyperglycaemic and antidyslipidaemic effects of *C. gynandra* under experimental conditions(53).

- *Anti-hyperglycaemic Potential*

Anti-hyperglycaemic activity involves the reduction of elevated blood glucose through mechanisms such as enhancement of insulin secretion, improvement of insulin sensitivity, stimulation of peripheral glucose uptake, and modulation of carbohydrate metabolism(54). Phytoconstituents including flavonoids, alkaloids, tannins, saponins, and phenolic compounds may influence glucose homeostasis through multiple pathways. Proposed mechanisms include protection of pancreatic β -cells, inhibition of carbohydrate-digesting enzymes such as α -amylase and α -glucosidase, enhancement of peripheral glucose utilization, and reduction of oxidative stress associated with chronic hyperglycaemia(55).

- *Analgesic Activity*

The analgesic activity of the ethanolic leaf extract of *Cleome gynandra* L. has been evaluated using the acetic acid-induced writhing model in mice. Oral administration of the extract at 300 mg/kg body weight produced 50.00% protection against writhing, compared with 69.50% protection produced by indomethacin at 10 mg/kg. These findings indicate that the leaf extract possesses significant peripheral analgesic activity, although its effect was lower than that of the standard drug(56).

Analgesic activity may involve central and/or peripheral modulation of pain pathways. Phytoconstituents such as flavonoids, alkaloids, tannins, terpenoids, and saponins may contribute to analgesic effects through modulation of inflammatory mediators, cyclooxygenase (COX), lipoxygenase (LOX), prostaglandin synthesis, and other nociceptive pathways(57,58). The analgesic potential of *C. gynandra* therefore supports its traditional use in the management of pain and inflammatory conditions.

- *Anti-Ulcer Activity*

The gastroprotective activity of the ethanolic leaf extract of *Cleome gynandra* L. has been investigated using aspirin-induced, ethanol-induced, and pylorus ligation-induced ulcer models in rats. Oral administration of the extract at 300 mg/kg body weight demonstrated significant anti-ulcer activity compared with the control group(56).

In the pylorus ligation model, the extract significantly reduced gastric volume, free acidity, and ulcer index. It also produced 55.76% protection against ethanol-induced gastric ulceration and 61.01% protection against aspirin-induced ulceration. These findings indicate that the ethanolic leaf extract possesses notable gastroprotective and anti-ulcer potential under experimental conditions(56).

- *Antifungal Activity*

Cleome gynandra L., commonly known as African spider flower, African cabbage, or dog mustard, has traditionally been used in some African communities for the management of fungal infections, including tinea capitis. In-vitro investigations conducted at Mbarara University of Science and Technology provided experimental support for its traditional antifungal application(59).

The antifungal activity of *C. gynandra* may be associated with secondary metabolites such as flavonoids, alkaloids, tannins, terpenoids, saponins, and phenolic compounds. These constituents may inhibit fungal growth through disruption of cell membrane integrity, interference with ergosterol-related processes, inhibition of spore germination, and induction of oxidative damage(60,61). The reported activity supports further investigation of *C. gynandra* as a potential source of natural antifungal compounds(61).

- *Antimicrobial Activity*

The antimicrobial activity of methanolic plant extracts has been evaluated using disc diffusion and microbroth dilution methods, with streptomycin and nystatin used as reference standards for bacterial and fungal organisms, respectively. The methanolic extract of *Cleome gynandra* L. showed notable antibacterial activity against *Staphylococcus aureus*, producing an inhibition zone of 22 ± 0.22 mm and MIC and MBC values of 0.039 mg/mL(62).

The antimicrobial effects of medicinal plants may be attributed to phytoconstituents such as alkaloids, flavonoids, tannins, terpenoids, saponins, and phenolic compounds. These compounds may inhibit microorganisms through disruption of cell wall and membrane integrity, interference with nucleic acid synthesis, inhibition of essential enzymes, and suppression of biofilm formation(63).

- *Anti-Bacterial Activity*

The antibacterial potential of *C. gynandra* may be associated with its diverse phytochemical composition. Alkaloids, flavonoids, tannins, terpenoids, saponins, and phenolic compounds can act against bacterial pathogens through multiple mechanisms, including membrane disruption, inhibition of essential enzymes and nucleic acid synthesis, and interference with biofilm development(63).

Further studies using purified constituents are required to establish the specific compounds and molecular mechanisms responsible for the antibacterial activity.

➤ Antidiarrhoeal Activity

The antidiarrhoeal activity reported for *Cleome viscosa* L. (family Capparaceae) has been evaluated using castor oil- and prostaglandin E₂ (PGE₂)-induced diarrhoeal models in rats. The methanolic whole-plant extract significantly reduced diarrhoeal responses, intestinal fluid accumulation, and gastrointestinal transit, suggesting effects on intestinal secretion and motility(64).

Antidiarrhoeal activity may involve reduction of intestinal hypersecretion, modulation of gastrointestinal motility, attenuation of inflammation, and protection of the intestinal mucosa. Phytoconstituents such as flavonoids, tannins, saponins, alkaloids, and phenolic compounds may contribute to these effects(65,66). These findings relate specifically to *C. viscosa* and provide experimental support for its traditional antidiarrhoeal use(64).

➤ Antipyretic Activity

Antipyretic activity refers to the ability of a substance to reduce elevated body temperature, primarily through modulation of hypothalamic thermoregulation and suppression of fever-associated mediators such as prostaglandins(67). Plant-derived compounds including flavonoids, alkaloids, tannins, terpenoids, and saponins may contribute to antipyretic effects by reducing prostaglandin synthesis and pro-inflammatory cytokine production(68).

The presence of these phytochemical classes in medicinal plants highlights their potential as natural sources of antipyretic agents and warrants further investigation of their mechanisms and therapeutic efficacy(68).

➤ Hepatoprotective Activity

The hepatoprotective potential of ethanolic leaf and root extracts of *Cleome gynandra* L. has been evaluated in carbon tetrachloride (CCl₄)-induced hepatotoxicity in albino rats. Extracts administered at 100 and 200 mg/kg significantly reduced elevated serum SGOT, SGPT, alkaline phosphatase (ALP), and total bilirubin levels compared with the CCl₄-treated control. The observed effects were comparable with those of silymarin, used as the standard hepatoprotective agent. The extracts also showed antioxidant activity, with IC₅₀ values comparable to ascorbic acid. Among the tested preparations, the ethanolic leaf extract demonstrated greater hepatoprotective activity than the root extract(69).

➤ Antinociceptive, Cytotoxic, And Antibacterial Activities

The methanolic leaf extract of *Cleome viscosa* L. has demonstrated antinociceptive, cytotoxic, and antibacterial activities in experimental models. In the acetic acid-induced writhing test, oral administration at 250 and 500 mg/kg significantly inhibited writhing responses compared with the standard drug diclofenac sodium(70).

The extract also exhibited cytotoxic activity in the brine shrimp (*Artemia salina*) lethality assay, with LC₅₀ and LC₉₀ values of 28.18 and 112.20 µg/mL, respectively. In vitro antibacterial activity was observed against *Staphylococcus saprophyticus*, *Shigella sonnei*, *Salmonella typhi*, *Vibrio cholerae*, *Streptococcus epidermidis*, *Shigella flexneri*, and *Staphylococcus aureus*, with inhibition zones ranging from 10.76 to 16.34 mm(70). These findings support the traditional medicinal relevance of *C. viscosa* and warrant further investigation of its bioactive constituents(70).

➤ Wound Healing Activity

Wound healing is a coordinated biological process involving inflammation, cellular proliferation, collagen deposition, angiogenesis, tissue formation, and re-epithelialization(71). Medicinal plants containing flavonoids, tannins, saponins, alkaloids, and phenolic compounds may support these processes through antioxidant, anti-inflammatory, antimicrobial, and tissue-regenerative effects(72).

Table 3 Summary of Reported Phytoconstituents, Pharmacological Activities, and Traditional Uses of *Cleome gynandra* L. (1,73–83)

S. No.	Plant part	Extract / preparation	Reported phytoconstituents	Documented pharmacological activities / uses
1	Leaves	Aqueous extract	Phenolic acids, tannins, saponins, vitamin C	Antidiarrhoeal, antipyretic, wound-healing and traditional tonic properties
2	Leaves	Ethanol extract	Flavonoids such as quercetin, rutin and kaempferol; alkaloids; terpenoids	Anti-inflammatory, analgesic, antimicrobial and antioxidant activities
3	Leaves	Methanolic extract	Flavonoids, triterpenoids, glycosides, carotenoids and tocopherols	Antidiabetic, potential anticancer, hepatoprotective and antioxidant activities
4	Seeds	Seed oil	Fixed oils containing linoleic, oleic and palmitic acids; sterols; proteins	Nutritional applications, skin-care potential and antimicrobial activity; source of essential fatty acids and proteins
5	Seeds	Methanolic extract	Phenolic compounds, amino acids and sterols	Antimicrobial and antioxidant activities
6	Seeds	Petroleum ether extract	Fatty acids and sterols	Antimicrobial activity and nutritional significance
7	Roots	Aqueous decoction	Alkaloids, glycosides, saponins and phenolic compounds	Traditional use for fever, gastrointestinal disorders, cough and asthma
8	Roots	Ethanol extract	Alkaloids, tannins and saponins	Anthelmintic and anti-inflammatory activities
9	Flowers / aerial parts	Ethanol extract	Flavonoids, triterpenoids and phenolic compounds	Antifungal activity, particularly against dermatophytes, and antimicrobial activity
10	Flowers / aerial parts	Methanolic extract	Flavonoids and phenolic compounds	Wound-healing and antioxidant activities
11	Stem	Aqueous extract	Tannins and alkaloids	Traditional digestive and supportive medicinal applications
12	Stem	Methanolic extract	Flavonoids, tannins and phenolic compounds	Antioxidant and antimicrobial activities
13	Whole plant	Aqueous / alcoholic extract	Diverse phytochemical constituents, including flavonoids, alkaloids, tannins, phenolics and vitamins	Traditional health-promoting use; antioxidant, antimicrobial, antitumour and antidiabetic potential

VI. CONCLUSION

Cleome gynandra L., commonly referred to as the spider plant, is a traditionally important medicinal and edible plant with considerable ethnomedicinal and nutritional significance. Pharmacognostical investigations of different plant parts, including leaves, stems, roots, flowers, fruits, and seeds, provide valuable diagnostic characteristics for accurate identification and authentication of the crude drug. Such morphological and microscopic features are particularly useful for maintaining the quality, purity, and consistency of plant-derived medicinal preparations.

Phytochemical investigations have demonstrated the presence of diverse bioactive constituents in *C. gynandra*, including flavonoids, alkaloids, glycosides, saponins, tannins, terpenoids, phenolic compounds, glucosinolates, proanthocyanidins, vitamins, β -carotene, and proteins. The occurrence of these chemically diverse constituents may contribute to the broad range of biological activities reported for the plant and provides a basis for further investigation of its therapeutic potential.

Available pharmacological evidence indicates that *C. gynandra* exhibits several promising biological activities, including antioxidant, anti-inflammatory, antimicrobial, analgesic, antidiabetic, hepatoprotective, anticancer,

immunomodulatory, wound-healing, and anthelmintic effects. These findings provide scientific support for several of its traditional applications. However, the available evidence is still largely based on preliminary experimental investigations, and the contribution of individual phytoconstituents to the observed activities requires further clarification.

In particular, the flowers of *C. gynandra* represent a relatively less explored plant part and may serve as a valuable source of phenolic and flavonoid compounds. Therefore, future studies should focus on the in-silico evaluation of flower-derived phytoconstituents against antioxidant- and antidiabetic-related molecular targets. Molecular docking and related computational approaches could be employed to investigate the possible interactions of identified flower compounds with selected targets associated with oxidative stress and glucose metabolism. Such computational findings, followed by appropriate in-vitro and in-vivo validation, may help establish structure-activity relationships and identify promising lead molecules.

Further research involving chromatographic isolation, structural characterization, molecular docking, molecular dynamics studies, toxicity prediction, experimental validation, and well-designed pharmacological investigations is required to establish the therapeutic relevance of the flower

constituents. Overall, *Cleome gynandra* L. possesses considerable pharmacognostical, phytochemical, nutritional, and pharmacological value, while its flower-derived constituents, particularly in relation to in-silico antioxidant and antidiabetic investigations, offer an interesting area for future research and potential therapeutic development.

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