



SYSTEMATIC REVIEW OF PHYTOCHEMISTRY AND PHARMACOLOGICAL ACTIVITIES OF RUELLIA TUBEROSA LINN

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ABSTRACT

Ruellia tuberosa L. is an herb belonging to the family Acanthaceae. Due to the presence of active chemical compounds such as alkaloids, flavonoids, triterpenoids, etc., it cures different ailments such as gonorrhoea, eye diseases, diabetes, and bronchitis. It also attracts many pollinators and has significant economic value. Therefore, the present study highlights its pharmacological, ethnomedicinal, ecological, and economic importance. **Keywords:** *Ruellia*, pharmacological uses traditional knowledge, secondary metabolites, **Introduction:** Since the earliest periods of human history, plants have been utilized for medicinal purposes. They are believed to possess natural healing properties, which makes them valuable in traditional and modern medicine. Pakistan's flora is particularly abundant in medicinal plants because of its varied climate, diverse soil types, and numerous ecological zones. Surveys indicate that the country is home to

approximately 6,000 species of flowering plants, of which around 400 to 600 species have recognized medicinal significance.^[1] The *Ruellia* genus, which comprises 250 species, is found in both tropical and temperate regions of both hemispheres. Most people use *Ruellia tuberosa* for ornamental purposes worldwide. Its origins can be traced back to tropical America and Southeast Asia, specifically Thailand, Peninsular Malaysia, and Java, as well as the tropics of India, Sri Lanka, and Africa (Chothani et al. 2020;^[5] Sharma et al. 2024). *Ruellia tuberosa* L. is an herb with tuberous roots. It belongs to the family Acanthaceae. It is commonly known as the Mexican bluebell, a large bellflower. The flowering and fruiting period is from June to February. It is easily identifiable due to its striking funnel-shaped,

violet-colored, 5-lobed corolla flower. It primarily inhabits moist and shady areas. It grows near the roadside, in grasslands, cultivated fields, and in xerophiles. It is widely distributed in Southeast Asia. It also attracts many pollinators such as butterflies and insects. Some butterflies, like the lemon pansy (*Junonia lemonias*) and mangrove buckeye (*Junonia genoveva*), pollinate *R. tuberosa* (Harinath et al. 2016).^[9] Apart from ecological significance, it also holds medicinal value, such as in diabetes, gonorrhea, urinary problems, and analgesics (Pandey and Singh 2018).^[12] Flowers of *R. tuberosa* are light bluish-purple due to the presence of the flavonoid pigment of anthocyanin, which is used as a natural dye in industries (Kampeerapappun et al. 2010).^[10]

Ethnobotany

Botanical characterization: The family Acanthaceae belongs to the class Eudicots and is placed under the order Lamiales. It is a large and diverse family of flowering plants, comprising approximately 250 genera and nearly 2,500 species worldwide. Members of this family are mainly distributed in tropical and subtropical regions, although some species are also found in temperate areas.

In Pakistan, the family Acanthaceae has a moderate representation. It includes about 18 genera and nearly 60 specific and infraspecific taxa. Among these, around 44 taxa are indigenous or native to the country, reflecting the adaptability of this family to Pakistan's varied climatic and ecological conditions.

Palynological (pollen-based) investigations of Acanthaceae in Pakistan began with preliminary studies that examined only a few selected taxa. These early investigations provided limited information about pollen morphology within the family. Later, more comprehensive palynological research was conducted, which significantly expanded the understanding of pollen characteristics. These detailed studies identified and described 11 distinct pollen types within the family Acanthaceae for the first time. This classification based on pollen morphology contributed greatly to taxonomic clarification and evolutionary understanding of the group.^[12,13]

DESCRIPTION

It is a glabrous or glabrescent herb up to 30-40 cm, much branched from a rootstock of numerous fleshy tubers. Leaves elliptic-obovate, obovate-oblong or elliptic-oblong, entire or undulate-crenate; petiole 1-2.2 cm long. Flowers are blue and 3 cm long in axillary and

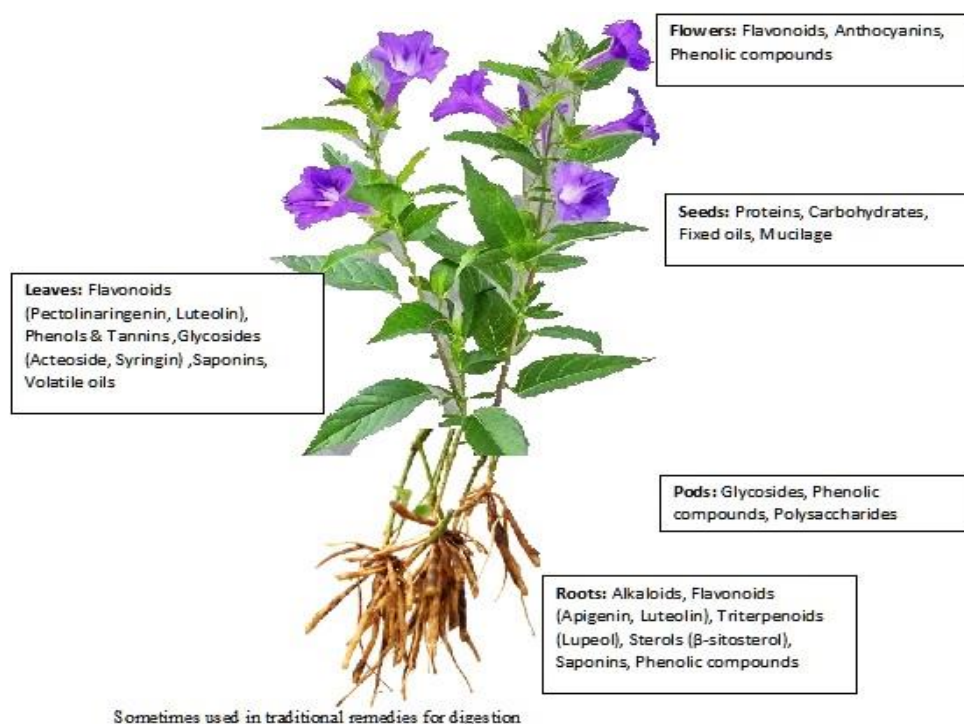
terminal cymes; bracts and bracteoles are narrow. Calyx segments are long, setaceous, hairy, or glandular. Capsule linear, 2-2.8 cm. Fruits a pod with 7-8 seeds (Saxena and Brahman 1995; Figure 1 & 2).

BIOACTIVE COMPOUNDS

It possesses bioactive compounds such as alkaloids, benzoxazinoids, flavonoids, lignans, phenolic compounds, saponins, tannins, triterpenoids, and sterols (Pandey and Singh 2018; Samy et al. 2015; Ariridran et al. 2011). Table 1: Some bioactive compounds reported from the *R. tuberosa* and their probable utilization.

These reported bioactive compounds are responsible for therapeutic uses Details are listed in Table 1.

Bioactive Components	Utilization
Flavonoids	Antioxidants help reduce oxidative stress and have anti-inflammatory and anti-cancer potential.
Alkaloids	These are known for their analgesic (pain-relieving) and anti-inflammatory effects.
Tannins	Possess astringent properties, which are beneficial for wound healing and treating infections.
Saponins	Known for their immune-boosting properties and may help reduce cholesterol levels.
Steroids	Exhibit anti-inflammatory and antimicrobial effects
Phenolic acids	These have strong antioxidant properties, which may help protect against cellular damage



Sometimes used in traditional remedies for digestion

ETHNOMEDICINAL USES

Researchers use the leaves to treat diabetes (Xu et al. 2020). Rajan et al. (2012) uses the roots to treat kidney diseases and whooping cough. Pandey and Singh (2018) use the leaves' decoction to treat gonorrhoea and ear diseases. Karle et al. (2022) use it to treat abdominal pain. People use the dried and ground root to treat sore eyes. You can use the decoction of leaves to treat bronchitis. You apply a paste of leaves externally to treat skin diseases, wounds, and boils. People use the seeds to treat spermatorrhea and leucorrhoea. Chothani et al. (2010) use the whole plant to treat bladder diseases. Alam et al. (2009) use the root to reduce toxicity and heal urinary tract inflammation.

Pharmacological actions of *Ruellia tuberosa*

It possesses anti-diabetic, antipyretic, analgesic, antioxidant, anti-hypertensive, anti-ulcer, anti-microbial, antinociceptive, anti-inflammatory, and gastroprotective properties (Afzal et al. 2015; Samy et al. 2015; Pandey and Singh 2018). Flowers of *R. tuberosa* possess anticancer activity (Guha et al. 2024).

1. Antinociceptive and Anti-inflammatory Activity

Ruellia tuberosa has been extensively evaluated for its antinociceptive and anti-inflammatory properties using standard experimental models. In acetic acid-induced writhing tests, the extract significantly reduces the number of writhes, indicating inhibition of peripheral pain mediators such as prostaglandins. In the hot plate test, an increase in latency time suggests central analgesic action, possibly involving modulation of opioid receptors or central pain pathways. Furthermore, the extract demonstrates significant inhibition of carrageenan-induced paw edema, a widely used model for acute inflammation. This effect is attributed to suppression of inflammatory mediators such as histamine, serotonin, and prostaglandins. The presence of flavonoids and phenolic compounds contributes to membrane stabilization and inhibition of lysosomal enzyme release, thereby reducing tissue damage. Additionally, antioxidant activity of the plant helps in reducing oxidative stress associated with inflammation. The combined peripheral and central analgesic effects, along with anti-inflammatory action, support the traditional use of *Ruellia tuberosa* in treating pain and inflammatory conditions and suggest its potential as a natural alternative to conventional non-steroidal anti-inflammatory drugs.^[19](Alam et al., 2009)

2. Antioxidant Activity

The antioxidant potential of *Ruellia tuberosa* is attributed to its rich phytochemical composition, particularly flavonoids, phenolics, and other secondary metabolites. These compounds exhibit strong free radical scavenging activity, as demonstrated by various *in vitro* assays such as DPPH, nitric oxide, and superoxide radical inhibition tests. The extract effectively neutralizes reactive oxygen species (ROS), thereby protecting cellular components like lipids, proteins, and DNA from oxidative damage. In addition to direct scavenging activity, *Ruellia tuberosa* enhances endogenous antioxidant defense mechanisms by increasing the activity of enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase. This dual mechanism plays a crucial role in maintaining cellular redox balance. The inhibition of nitric oxide production further contributes to its anti-inflammatory effects, linking antioxidant and anti-inflammatory pathways. Oxidative stress is a key factor in the pathogenesis of several chronic diseases, including cancer, cardiovascular disorders, and neurodegenerative conditions. Therefore, the strong antioxidant activity of *Ruellia tuberosa* highlights its therapeutic potential in preventing and managing oxidative stress-related disorders.^[20] (Pham et al.).

3. Antiulcer and Gastroprotective Activity

Ruellia tuberosa has demonstrated significant antiulcer and gastroprotective effects in experimental models such as pylorus ligation-induced gastric ulcers. The hydroethanolic leaf extract significantly reduces gastric volume, total acidity, and ulcer index while increasing gastric pH, indicating potent antisecretory activity. By decreasing acid and pepsin secretion, the extract minimizes damage to the gastric mucosa. Additionally, it enhances mucosal defense mechanisms by increasing mucus secretion and strengthening the protective barrier of the stomach lining. The gastroprotective effect is further supported by its antioxidant properties, which help in scavenging free radicals and reducing oxidative stress-induced mucosal injury. Phytoconstituents such as flavonoids and tannins contribute to cytoprotective effects by promoting tissue repair and reducing inflammation. The root extract has also shown similar protective effects, suggesting that multiple parts of the plant possess therapeutic potential. These combined actions help in restoring the balance between aggressive and defensive factors in the gastric environment, thereby preventing ulcer formation and promoting healing.^{[21],[22]} (Manikandan & Arokia Doss; Arambewela et al., 2003).

4. Wound Healing Activity

Ruellia tuberosa has been reported to possess significant wound healing properties, as demonstrated in excision and incision wound models. The application of the plant extract results in accelerated wound contraction, reduced epithelialization period, and increased tensile strength of the healed tissue. These effects indicate enhanced collagen synthesis, improved fibroblast proliferation, and better tissue remodeling. Collagen plays a crucial role in wound healing by providing structural integrity to the newly formed tissue. The antioxidant properties of the plant help in reducing oxidative stress at the wound site, which is essential for proper healing. Additionally, its anti-inflammatory action reduces swelling and prevents further tissue damage. The presence of flavonoids and tannins promotes angiogenesis and granulation tissue formation, further aiding in the healing process. Moreover, the antimicrobial properties of *Ruellia tuberosa* help prevent infection, which is a major factor delaying wound healing. These combined mechanisms make the plant an effective natural agent for promoting wound repair and tissue regeneration.^[23] (Ranjani & Manjula).

5. Anticancer Activity

Ruellia tuberosa has shown promising anticancer activity in both in vivo and in vitro studies, indicating its potential as a source of novel anticancer agents. In animal models such as Ehrlich Ascites Carcinoma (EAC)-induced solid tumors, the extract significantly reduces tumor volume and weight, suggesting inhibition of tumor growth and progression. In vitro studies on cancer cell lines, including breast cancer (MCF-7) and hepatoma cells, have demonstrated that the extract induces apoptosis and causes cell cycle arrest, thereby inhibiting cell proliferation. The mechanism involves the generation of reactive oxygen species (ROS), which leads to oxidative stress, DNA damage, and activation of apoptotic pathways. Additionally, the extract enhances antioxidant enzyme activity, contributing to its chemopreventive effects. Bioactive compounds such as flavonoids and phenolics are believed to play a crucial role in modulating signaling pathways involved in cancer development. The ability of *Ruellia tuberosa* to target multiple pathways, including oxidative stress, apoptosis, and cell cycle regulation, highlights its potential as a multi-targeted anticancer agent.^{[24],[25],[26],[27]} (Reddy et al., 2013; Lem et al., 2022; Guha et al., 2024)

6. Antidiabetic Activity

Ruellia tuberosa has been widely reported for its significant antidiabetic potential, particularly in streptozotocin (STZ)- and alloxan-induced diabetic animal models. The plant extract effectively reduces blood glucose levels and improves glucose tolerance, suggesting its role in glycemic control. The mechanism of action is believed to involve enhancement of insulin secretion from pancreatic β -cells and increased peripheral glucose utilization. Additionally, the extract inhibits carbohydrate-digesting enzymes such as α -amylase and α -glucosidase, thereby reducing postprandial hyperglycemia. The presence of flavonoids, saponins, and phenolic compounds contributes to its hypoglycemic activity. Moreover, *Ruellia tuberosa* has been shown to improve lipid profiles and reduce oxidative stress in diabetic conditions, indicating its protective role against diabetes-related complications. Its antioxidant properties further help in preserving pancreatic cell integrity and preventing β -cell damage. These combined effects support its traditional use in diabetes management and highlight its potential as a natural antidiabetic agent^[29] (Arambewela et al.; various experimental studies).

7. Hepatoprotective Activity

The hepatoprotective activity of *Ruellia tuberosa* has been demonstrated in experimental models of liver injury induced by toxic agents such as carbon tetrachloride (CCl_4) and paracetamol. The extract significantly reduces elevated levels of liver enzymes such as serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), and alkaline phosphatase (ALP), indicating restoration of normal liver function. The protective effect is primarily attributed to its antioxidant properties, which help in scavenging free radicals and preventing lipid peroxidation of hepatic cell membranes. Additionally, the phytoconstituents present in the plant, particularly flavonoids and phenolics, stabilize hepatocyte membranes and promote regeneration of damaged liver cells. The extract also enhances endogenous antioxidant enzyme activity, further contributing to hepatoprotection. These findings suggest that *Ruellia tuberosa* can effectively protect the liver against chemical-induced toxicity and may be useful in the management of liver disorders.^[30] (reported in experimental pharmacological studies).

8. Antimicrobial Activity

Ruellia tuberosa exhibits notable antimicrobial activity against a wide range of pathogenic microorganisms, including both Gram-positive and Gram-negative bacteria as well as certain

fungus species. Various extracts of the plant, particularly methanolic and ethanolic extracts, have shown inhibitory effects against organisms such as *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. The antimicrobial activity is mainly attributed to the presence of bioactive compounds such as flavonoids, alkaloids, tannins, and saponins, which disrupt microbial cell walls, inhibit protein synthesis, and interfere with essential metabolic pathways. Additionally, the antioxidant properties of the plant may enhance its antimicrobial effect by reducing oxidative stress in infected tissues. This activity supports the traditional use of *Ruellia tuberosa* in treating infections and wound-related complications. The broad-spectrum antimicrobial potential of the plant suggests its possible application in the development of natural antimicrobial agents.^[31] (various in vitro studies on plant extracts).

9. Neuroprotective Activity

Emerging studies suggest that *Ruellia tuberosa* possesses neuroprotective potential, primarily due to its antioxidant and anti-inflammatory properties. The plant extract has been shown to reduce oxidative stress in neuronal cells by scavenging free radicals and enhancing antioxidant enzyme activity. This helps in preventing neuronal damage caused by reactive oxygen species, which is a major factor in neurodegenerative diseases such as Alzheimer's and Parkinson's disorders. Additionally, the anti-inflammatory activity of the plant reduces neuroinflammation, thereby protecting neural tissues from damage. Certain phytochemicals present in *Ruellia tuberosa* may also modulate neurotransmitter levels and improve cognitive function. Although the exact mechanism is still under investigation, the combined antioxidant and anti-inflammatory actions suggest its potential role in neuroprotection. These findings indicate that *Ruellia tuberosa* could be explored further for its therapeutic applications in neurological disorders.^[32] (reported in preliminary experimental studies).

10. Analgesic and Antipyretic Activity

Ruellia tuberosa has demonstrated significant analgesic and antipyretic activities in various experimental models, supporting its traditional use in the management of pain and fever. The analgesic effect is evidenced by a reduction in pain responses in models such as acetic acid-induced writhing and hot plate tests, indicating both peripheral and central mechanisms of action. The peripheral analgesic effect is primarily associated with inhibition of prostaglandin synthesis, which plays a key role in pain perception, while the central effect may involve modulation of pain pathways in the central nervous system. In addition to its analgesic properties, *Ruellia tuberosa* exhibits notable antipyretic activity, as demonstrated in yeast-

induced pyrexia models. The extract significantly reduces elevated body temperature, likely by inhibiting prostaglandin E2 (PGE2) synthesis in the hypothalamus, which is responsible for regulating body temperature during fever. The presence of flavonoids and phenolic compounds contributes to both analgesic and antipyretic effects through their anti-inflammatory and antioxidant properties.^[28] Overall, these findings indicate that *Ruellia tuberosa* possesses dual analgesic and antipyretic activities, making it a promising natural alternative for the treatment of pain and fever (Alam et al., 2009; related experimental studies).

OTHER USES

The flower is used as a natural dye for textiles (Kampeerappun et al. 2010). In Taiwan, it is used as an herbal drink (Arirudran et al. 2011).

CONCLUSION

Ruellia tuberosa L. is a medicinal plant widely recognized for its bioactive components and potential therapeutic uses. Also known as Cracker Plant or Minnieroot, this herb is native to tropical areas and is often found in regions of Asia, South America, and Africa. Here's an overview of its bioactive components and medicinal uses (Figure 3). In traditional practices, *Ruellia tuberosa* is used as a tea or poultice, depending on the intended therapeutic effect. More research is ongoing to validate these medicinal uses and potentially expand its applications in modern medicine.

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