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### A review on the Phytochemistry, Medicinal Properties and Pharmacological activities of *Spermacoce latifolia* and *Celastrus paniculatus*

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#### Abstract

*Spermacoce latifolia* and *Celastrus paniculatus* are two medicinal plants with significant ethnobotanical relevance and diverse pharmacological activities. *Spermacoce latifolia*, commonly used in traditional medicine for its anti-inflammatory, antimicrobial, antioxidant, neuroprotective, and anti-diabetic properties, contains bioactive compounds such as flavonoids, alkaloids, and phenolic compounds. These compounds exert their effects through the inhibition of pro-inflammatory pathways, scavenging of free radicals, and modulation of metabolic and neurological functions. *Celastrus paniculatus*, known as the intellect tree, is prominent in Ayurvedic medicine for its cognitive-enhancing and neuroprotective properties. Its key bioactive compounds, including celastrene and paniculatine, contribute to its pharmacological profile by enhancing cholinergic neurotransmission, inhibiting oxidative stress, and reducing inflammation. Both plants have demonstrated favorable safety profiles in preclinical studies, showing low toxicity at traditional dosages. Limited human studies report mild and transient side effects, supporting the traditional use of these plants. However, there remains a need for comprehensive clinical studies to confirm their safety and efficacy, particularly for long-term use and in special populations. This review highlights the pharmacological mechanisms, traditional uses, and safety profiles of *Spermacoce latifolia* and *Celastrus paniculatus*, emphasizing their potential as therapeutic agents. Future research should focus on detailed molecular studies and extensive clinical trials to fully explore their medicinal potential and ensure their safe application in modern medicine.

**Keywords:** *Spermacoce latifolia*, *Celastrus paniculatus*, medicinal plants, neuroprotective effects, anti-inflammatory, antioxidant, cognitive enhancement, ethnobotanical uses.

## Introduction

Medicinal plants have played a crucial role in human health and wellness since ancient times, forming the foundation of both traditional and modern medicine systems[1]. Their significance spans diverse cultures and geographies, offering a rich repository of therapeutic compounds that continue to be explored for their potential in treating various ailments[2]. Among the many medicinal plants that have gained prominence, *Spermacoce latifolia* and *Celastrus paniculatus* stand out for their historical use and pharmacological potential in traditional medicine practices[3]. The use of medicinal plants predates written history, with evidence dating back to the Paleolithic age. Early civilizations, including those in ancient Egypt, China, India, and Greece, documented the healing properties of plants and integrated them into their medical practices[4]. Traditional medicine systems, such as Ayurveda, Traditional Chinese Medicine (TCM), Unani, and Indigenous healing traditions, developed sophisticated frameworks for understanding the therapeutic benefits of plants[5]. These systems emphasize a holistic approach to health, viewing the body as interconnected with nature and advocating for the use of botanical remedies to restore balance and promote well-being[6]. In modern times, the study of medicinal plants has expanded with advances in scientific research and technology. Many pharmaceutical drugs trace their origins to plant sources or are inspired by traditional knowledge of herbal remedies[7]. For example, aspirin derives from salicylic acid found in willow bark, while the cancer drug paclitaxel originates from the Pacific yew tree. Moreover, the trend towards natural and herbal medicines has grown as people seek alternatives to synthetic drugs, driven by concerns over side effects and a renewed appreciation for traditional healing practices[8]. Medicinal plants contribute significantly to global healthcare, providing sustainable and accessible treatment options, especially in developing countries where access to conventional medicine may be limited[9]. Their importance extends beyond their therapeutic value; they also play a crucial role in biodiversity conservation and cultural heritage preservation. Thus, the study and preservation of medicinal plants are not only scientific endeavors but also ethical and cultural imperatives[10].

*Spermacoce latifolia*, also referred to as broadleaf false buttonweed, originates from tropical and subtropical regions, especially in Asia and Africa. This plant has been utilized in traditional medicinal practices for its health benefits[11]. In Ayurveda, the traditional medicine system of India, it is called "Aparajita." It is highly regarded for its anti-inflammatory, antimicrobial, and wound-healing properties[12]. The plant is rich in bioactive compounds like alkaloids, flavonoids, and phenolic compounds, which are responsible for its therapeutic effects. Research has confirmed its antioxidant properties and investigated its potential in treating inflammation and infections[13].

*Celastrus paniculatus*, also known as black oil plant or intellect tree, is indigenous to the Indian subcontinent. It holds a prominent place in Ayurvedic medicine, where it is regarded as a "Medhya Rasayana" or brain tonic[14]. The seeds of *Celastrus paniculatus* are rich in bioactive compounds including triterpenoids (e.g., celastrene) and alkaloids (e.g., paniculatine). Traditional uses include enhancing cognitive function, improving memory, and alleviating neurological disorders[15]. Scientific research has supported its neuroprotective, anti-inflammatory, and antioxidant properties, suggesting potential therapeutic applications in neurodegenerative diseases such as Alzheimer's and Parkinson's[16].

## 2. Botanical Description and Distribution

### *Spermacoce latifolia*

#### Morphology:

*Spermacoce latifolia*, also known as broadleaf false buttonweed, is a perennial herb in the Rubiaceae family[17]. It usually grows upright, reaching a height of 30-60 cm. The plant

features opposite leaves that are broad, ovate to elliptic, and can grow up to 7 cm long. The leaves are glossy green with prominent veins and smooth edges. *Spermacoce latifolia* produces small white flowers, clustered at the ends of branches. Each flower has four petals and is surrounded by green sepals[18].



Figure 1: morphology of *Spermacoce latifolia*

**Habitat:**

*Spermacoce latifolia* thrives in tropical and subtropical regions, often found in moist, open areas such as grasslands, fields, and along roadsides. It prefers well-drained soils and can tolerate both partial shade and full sun exposure[19].

**Geographical Distribution:**

This species is native to various parts of Asia and Africa. It is widely distributed in countries like India, Sri Lanka, Bangladesh, Thailand, Vietnam, Malaysia, Nigeria, and Ghana. *Spermacoce latifolia* has also been introduced and naturalized in other tropical regions around the world due to its medicinal and ornamental value[20].

***Celastrus paniculatus***

**Morphology:**

*Celastrus paniculatus*, also known as black oil plant or intellect tree, is a deciduous climbing shrub belonging to the Celastraceae family. It features slender, wiry stems that twine around support structures as it grows[21]. The leaves are elliptical, glossy green, and arranged alternately along the stems. They are about 5-10 cm in length, with finely toothed margins. The flowers of *Celastrus paniculatus* are small, greenish-white, and appear in dense clusters (panicles) at the ends of branches. The fruit is a capsule that contains seeds covered with a bright red aril[22].



Figure 2: morphology of *Celastrus paniculatus*

**Habitat:**

*Celastrus paniculatus* is native to the Indian subcontinent and thrives in tropical and

subtropical climates. It is commonly found in forests, scrublands, and along riverbanks. The plant prefers well-drained soils and can grow in both full sun and partial shade[23].

### **Geographical Distribution:**

This species is primarily distributed throughout India, including regions such as the Western Ghats, Eastern Ghats, and central and northern plains. It is also found in neighboring countries like Nepal and Bangladesh. *Celastrus paniculatus* has been cultivated in gardens and naturalized in other parts of Asia, including Sri Lanka and Myanmar, due to its medicinal and economic importance[24].

### **3. Phytochemical Composition**

Phytochemical analysis of plants such as *Spermacoce latifolia* reveals a complex array of bioactive compounds that contribute to their medicinal properties[12]. These compounds are classified into several groups, each with distinct chemical structures and physiological effects[16,5]. Understanding the phytochemical composition of *Spermacoce latifolia* is essential for elucidating its therapeutic potential and exploring possible applications in medicine and healthcare[25].

#### **1. Alkaloids**

Alkaloids are nitrogen-containing compounds with diverse biological activities. In *Spermacoce latifolia*, several alkaloids have been identified, each contributing to the plant's pharmacological profile. Examples of alkaloids found in *Spermacoce latifolia* include:

**Caffeine:** Caffeine (1,3,7-trimethylxanthine) is a well-known alkaloid found in *Spermacoce latifolia*. It acts as a central nervous system stimulant and has been studied for its effects on alertness and cognitive function[25].

**Vasicine:** Vasicine (peganine) is another alkaloid present in *Spermacoce latifolia*. It exhibits bronchodilator properties and has been traditionally used in Ayurvedic medicine for respiratory conditions like asthma and bronchitis[26].

**Vasicinone:** Vasicinone is a related alkaloid with similar bronchodilator effects. It contributes to the plant's therapeutic potential in treating respiratory ailments[27].

#### **2. Flavonoids**

Flavonoids are polyphenolic compounds known for their antioxidant and anti-inflammatory properties. They are abundant in *Spermacoce latifolia* and contribute significantly to its medicinal benefits[28].

**Kaempferol:** Kaempferol is a flavonol found in many plants, including *Spermacoce latifolia*. It exhibits antioxidant and anti-inflammatory activities and has potential applications in protecting against oxidative stress-related diseases[29].

**Quercetin:** Quercetin is a flavonoid with potent antioxidant properties. It helps neutralize free radicals in the body and has been studied for its potential in reducing inflammation and supporting cardiovascular health[30].

#### **3. Terpenoids**

Terpenoids are a diverse class of compounds derived from the basic building blocks of isoprene. They contribute to the fragrance and therapeutic properties of plants. In *Spermacoce*

latifolia, terpenoids play a crucial role in its medicinal effects[31].

***β-Caryophyllene:***  $\beta$ -Caryophyllene is a sesquiterpene found in many medicinal plants, including *Spermacoce latifolia*. It exhibits anti-inflammatory properties by interacting with cannabinoid receptors in the body's endocannabinoid system[32].

***Limonene:*** Limonene is a monoterpene known for its citrusy aroma. It has antioxidant and anti-inflammatory properties and is found in the essential oils of *Spermacoce latifolia*, contributing to its therapeutic benefits[33].

#### 4. Phenolic Compounds

Phenolic compounds are aromatic secondary metabolites with diverse biological activities, including antioxidant, anti-inflammatory, and anticancer properties. They are abundant in *Spermacoce latifolia* and contribute significantly to its medicinal value[13,9]. Examples of phenolic compounds in *Spermacoce latifolia* include:

***Rosmarinic acid:*** Rosmarinic acid is a hydroxycinnamic acid derivative with strong antioxidant and anti-inflammatory effects. It has been studied for its potential in protecting against oxidative stress-related diseases and supporting immune function[34].

***Chlorogenic acid:*** Chlorogenic acid is a phenolic acid found in many plants, including *Spermacoce latifolia*. It exhibits antioxidant properties and has been investigated for its role in improving cardiovascular health and supporting weight management[35].

Table 1: Comparative Analysis of Bioactive Compounds in *Spermacoce latifolia* and *Celastrus paniculatus*

Bioactive Compound	<i>Spermacoce latifolia</i>	<i>Celastrus paniculatus</i>	References
<b>Phenolic Compounds</b>	High content, contributing to antioxidant activity	Abundant, contributing to antioxidant and anti-inflammatory effects	[15]
<b>Flavonoids</b>	Present, provide antioxidant and anti-inflammatory benefits	Present, provide antioxidant, anti-inflammatory, and neuroprotective effects	[19]
<b>Alkaloids</b>	Significant presence, involved in medicinal properties	Present, contributing to various therapeutic effects	[22]
<b>Triterpenoids</b>	Not prominently reported	High content, contributing to anti-inflammatory and neuroprotective effects	[3]
<b>Celastrol</b>	Not present	Major bioactive compound, known for anti-inflammatory and anticancer properties	[18]
<b>Saponins</b>	Present, involved in antimicrobial and anti-inflammatory activities	Present, contributing to various medicinal properties	[15]
<b>Essential Oils</b>	Contains various essential oils with therapeutic properties	Contains various essential oils, contributing to its medicinal effects	[3]

<b>Tannins</b>	Present, provide antimicrobial and astringent properties	Present, contributing to antimicrobial and antioxidant activities	[20]
<b>Steroids</b>	Present, involved in anti-inflammatory effects	Present, contributing to anti-inflammatory and therapeutic effects	[31]

## 5. Other Bioactive Compounds

In addition to alkaloids, flavonoids, terpenoids, and phenolic compounds, *Spermacoce latifolia* contains various other bioactive compounds that contribute to its medicinal properties. These include:

**Tannins:** Tannins are polyphenolic compounds known for their astringent properties. They have been traditionally used in herbal medicine for their ability to treat diarrhea and as wound-healing agents[36].

**Saponins:** Saponins are glycosides with foaming properties. They have been studied for their potential in lowering cholesterol levels and supporting immune function.

**Resins:** Resins are mixtures of various compounds, including terpenes and phenols. They contribute to the plant's defense mechanisms and may have therapeutic effects in traditional medicine practices[37].

### Phytochemical Composition of *Celastrus paniculatus*

*Celastrus paniculatus*, commonly known as the black oil plant or intellect tree, is renowned for its diverse array of bioactive compounds[22]. These compounds contribute to its wide range of pharmacological activities and traditional uses, particularly in enhancing cognitive function and treating neurological disorders[10]. The major classes of phytochemicals in *Celastrus paniculatus* include triterpenoids, alkaloids, flavonoids, and other bioactive compounds[38].

#### Phytochemical Constituents of *Celastrus paniculatus*

### 1. Triterpenoids

Triterpenoids are a class of chemical compounds composed of three terpene units and often exhibit various therapeutic properties. *Celastrus paniculatus* is rich in triterpenoids, which contribute significantly to its medicinal value[39].

**Celastrine:** Celastrine is a triterpenoid compound found in the seeds of *Celastrus paniculatus*. Its chemical structure includes a complex arrangement of carbon rings typical of triterpenoids. Celastrine is known for its neuroprotective properties, supporting cognitive function and memory. It has been studied for its potential in treating neurodegenerative diseases such as Alzheimer's and Parkinson's disease[40].

**Celastrol:** Another important triterpenoid in *Celastrus paniculatus* is celastrol. Celastrol exhibits potent anti-inflammatory and antioxidant activities, making it a candidate for research in the treatment of inflammatory conditions and diseases involving oxidative stress[41].

## 2. Alkaloids

Alkaloids are nitrogen-containing compounds that often have significant pharmacological effects. In *Celastrus paniculatus*, alkaloids contribute to its cognitive-enhancing and neuroprotective properties[42].

**Paniculatine:** Paniculatine is an alkaloid unique to *Celastrus paniculatus*. Its chemical structure is characterized by nitrogen atoms within complex carbon frameworks. Paniculatine has been traditionally used for its memory-enhancing effects and its potential to support neurological health[43].

**B-Sitosterol:** Although primarily known as a phytosterol, B-Sitosterol in *Celastrus paniculatus* also has notable alkaloid properties. It is recognized for its cholesterol-lowering effects and potential benefits in promoting cardiovascular health[44].

## 3. Flavonoids

Flavonoids are polyphenolic compounds known for their antioxidant, anti-inflammatory, and neuroprotective properties. They are present in various parts of *Celastrus paniculatus* and contribute to its therapeutic effects[45].

**Quercetin:** Quercetin, a flavonoid that has been extensively researched, is known for its strong antioxidant capabilities. In *Celastrus paniculatus*, quercetin plays a role in neutralizing free radicals and safeguarding cells from oxidative harm. Additionally, it has anti-inflammatory properties, which can be advantageous for conditions associated with chronic inflammation[46].

**Kaempferol:** Kaempferol, a flavonoid found in *Celastrus paniculatus*, possesses antioxidant and anti-inflammatory properties. Research indicates that it may play a role in lowering the risk of chronic conditions like heart disease and cancer[47].

## 4. Other Bioactive Compounds

In addition to triterpenoids, alkaloids, and flavonoids, *Celastrus paniculatus* contains a variety of other bioactive compounds that enhance its medicinal properties.

**Fatty Acids:** The seeds of *Celastrus paniculatus* are rich in essential fatty acids, including linoleic acid and oleic acid. These fatty acids are crucial for maintaining cell membrane integrity and have anti-inflammatory and neuroprotective effects[48].

**Saponins:** Saponins are glycosides with foaming characteristics. They possess a range of pharmacological activities, including anti-inflammatory, antimicrobial, and immunomodulatory effects. In *Celastrus paniculatus*, saponins contribute to the plant's overall therapeutic potential[49].

**Steroids:** Steroidal compounds in *Celastrus paniculatus*, such as stigmasterol, are known for their anti-inflammatory and cholesterol-lowering properties. These compounds play a role in maintaining cardiovascular health and reducing inflammation[50].

**Tannins:** Tannins are polyphenolic compounds that have astringent properties. They are traditionally used to treat diarrhea and promote wound healing due to their ability to precipitate proteins and form protective layers on tissues[51].

Table2: Medicinal Properties of *Spermacoce latifolia* and *Celastrus paniculatus*

Medicinal Property	<i>Spermacoce latifolia</i>	<i>Celastrus paniculatus</i>	References
<b>Antioxidant Activity</b>	Rich in phenolic compounds, flavonoids, and alkaloids, neutralizes free radicals, protects cells from oxidative damage	High content of polyphenolic compounds, flavonoids, and triterpenoids, enhances endogenous antioxidant enzymes	[27]
<b>Anti-inflammatory Effects</b>	Inhibits production of pro-inflammatory cytokines, reduces activity of COX-2 and LOX enzymes	Compounds like celastrol suppress NF- $\kappa$ B activation, reduce production of cytokines and COX-2, iNOS enzymes	[19]
<b>Neuroprotective Effects</b>	Prevents neuronal apoptosis, reduces oxidative stress and inflammation, inhibits AChE to improve cognitive function	Protects brain cells, reduces oxidative stress and inflammation, improves memory and cognitive functions	[20]
<b>Anticancer Potential</b>	Exhibits cytotoxic effects on various cancer cell lines, induces apoptosis, inhibits cell proliferation	Contains bioactive compounds that inhibit cancer cell growth, induce apoptosis, and disrupt cell signaling pathways	[39]
<b>Antimicrobial Properties</b>	Effective against various bacterial and fungal strains, possesses significant antimicrobial activity	Exhibits antibacterial and antifungal properties, effective against multiple pathogens	[44]
<b>Wound Healing</b>	Accelerates wound healing process, promotes tissue regeneration and repair	Enhances healing of wounds, supports tissue repair and regeneration	[12]
<b>Diabetes Management</b>	Improves insulin sensitivity, lowers blood glucose levels, protects pancreatic $\beta$ -cells from oxidative damage	Lowers blood glucose, inhibits carbohydrate-digesting enzymes, enhances glucose uptake by cells	[46]

### Traditional Uses

The rich heritage of traditional medicine systems around the world has long recognized the therapeutic potential of plants like *Spermacoce latifolia* and *Celastrus paniculatus*. These plants have been integral to various cultural practices, providing remedies for a wide range of ailments[52].

### Ethnobotanical Uses of *Spermacoce latifolia*

*Spermacoce latifolia*, commonly known as broadleaf false buttonweed, has a long history of use in traditional medicine across different cultures, particularly in tropical and subtropical regions[53].

### **1. Indian Traditional Medicine (Ayurveda and Siddha Systems)**

In Indian traditional medicine, especially within the Ayurveda and Siddha systems, *Spermacoce latifolia* is known as "Aparajita." It is revered for its anti-inflammatory, antimicrobial, and wound-healing properties[19]. The leaves and roots are often used to prepare decoctions or poultices for treating skin infections, wounds, and ulcers. Additionally, the plant is used to alleviate respiratory conditions such as asthma and bronchitis, where its bronchodilator properties help in easing breathing[54].

### **2. African Traditional Medicine**

In African traditional medicine, *Spermacoce latifolia* is employed for its broad therapeutic effects. Traditional healers use the plant to treat gastrointestinal disorders, including diarrhea and dysentery[29]. The anti-inflammatory and antimicrobial properties of the plant are harnessed to manage infections and promote digestive health. In some regions, it is also used to relieve fever and as a general health tonic[33].

### **3. Southeast Asian Traditional Medicine**

In countries like Thailand and Malaysia, *Spermacoce latifolia* is integrated into traditional medicinal practices to address various ailments. The plant is used to treat urinary tract infections and kidney disorders due to its diuretic properties[2,9]. It is also employed in the management of menstrual irregularities and to reduce pain and inflammation associated with rheumatism and arthritis[44].

### **4. Indigenous Healing Practices**

Various indigenous communities across its native range use *Spermacoce latifolia* in their healing rituals and daily health practices[18]. The plant is often applied topically as a paste for treating skin conditions and insect bites. Its use in treating fever, colds, and general body pain highlights its versatility and importance in traditional health care[45].

### **Ethnobotanical Uses of *Celastrus paniculatus***

*Celastrus paniculatus*, also known as the black oil plant or intellect tree, is a cornerstone of traditional medicine systems in the Indian subcontinent and has gained attention for its potent cognitive-enhancing properties[23].

#### **1. Ayurveda**

In Ayurveda, *Celastrus paniculatus* is known as "Jyotishmati" and is classified as a "Medhya Rasayana," which means it is a tonic for the brain and intellect. Ayurvedic practitioners have long used the seeds of *Celastrus paniculatus* to enhance memory, intelligence, and overall cognitive function[29]. The oil extracted from the seeds, known as "Jyotishmati oil," is used in various formulations to treat mental fatigue, stress, anxiety, and depression. It is also believed to improve concentration and learning capabilities[46].

#### **2. Traditional Indian Medicine (Other Systems)**

Beyond Ayurveda, *Celastrus paniculatus* is utilized in other traditional Indian medical systems such as Unani and Siddha. In Unani medicine, the plant is used to treat neurological disorders and enhance mental clarity[44]. It is also employed to manage joint pain and inflammation. Siddha medicine integrates *Celastrus paniculatus* into treatments for a variety of ailments, including liver disorders, digestive issues, and as a general tonic to boost vitality and health[55].

### 3. Folk Medicine

In rural and tribal areas of India, *Celastrus paniculatus* is a common remedy for a range of health issues[10]. The seeds are often chewed or ground into a powder and mixed with honey or ghee to enhance memory and cognitive function. The plant is also used to treat snake bites and other venomous stings, leveraging its believed detoxifying properties[56].

### 4. Modern Applications and Integration

While deeply rooted in traditional practices, the therapeutic potential of *Celastrus paniculatus* has also found a place in modern alternative medicine[16]. The plant is marketed in various forms, such as capsules, tinctures, and oils, for its nootropic (cognitive-enhancing) effects. It is increasingly incorporated into dietary supplements aimed at improving mental performance, reducing stress, and supporting overall brain health[57].

### 5. Medicinal Properties

#### Pharmacological Properties of *Spermacoce latifolia*

##### Antioxidant Activity

*Spermacoce latifolia* shows notable antioxidant properties attributed to its high levels of phenolic compounds, flavonoids, and alkaloids. Antioxidants are essential for counteracting free radicals, unstable molecules that can harm cells and contribute to chronic illnesses such as cancer, cardiovascular diseases, and neurodegenerative disorders[58,3]. Extracts from the plant have undergone extensive testing in both laboratory and animal studies, demonstrating their ability to neutralize free radicals, decrease oxidative stress, and protect against lipid peroxidation. These findings indicate that *Spermacoce latifolia* may have potential in preventing and managing conditions associated with oxidative damage[23].

##### Anti-inflammatory Activity

Inflammation is a biological response to harmful stimuli, but chronic inflammation is implicated in numerous diseases, including arthritis, asthma, and cardiovascular diseases[10]. *Spermacoce latifolia* has been traditionally used to treat inflammatory conditions, and scientific studies have validated these traditional uses[34]. The plant contains bioactive compounds like alkaloids and flavonoids, which inhibit the production of pro-inflammatory cytokines and enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX)[23]. These anti-inflammatory properties have been demonstrated in animal models where *Spermacoce latifolia* extracts reduced edema and other markers of inflammation, indicating its potential as a natural anti-inflammatory agent[59].

##### Antimicrobial Activity

*Spermacoce latifolia* possesses strong antimicrobial properties, making it effective against a variety of pathogenic bacteria, fungi, and viruses. The plant's extracts have shown inhibitory effects on bacterial strains like *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*[32]. These antimicrobial activities are attributed to the presence of alkaloids, flavonoids, and terpenoids, which disrupt microbial cell walls and inhibit microbial enzyme activity. The broad-spectrum antimicrobial efficacy of *Spermacoce latifolia* supports its traditional use in treating infections and supports the development of novel antimicrobial agents derived from this plant[60].

##### Anticancer Activity

Researchers are actively investigating the potential anticancer properties of *Spermacoce latifolia*. Extracts from the plant have demonstrated cytotoxic effects against various types of cancer cells, such as breast cancer, liver cancer, and leukemia[1,3]. These anticancer effects

are primarily attributed to bioactive compounds such as phenolics, flavonoids, and alkaloids. These compounds induce apoptosis (programmed cell death) in cancer cells, inhibit cell proliferation, and disrupt signaling pathways crucial for cancer cell survival[18]. Studies indicate that these compounds can also halt the cell cycle and activate caspase enzymes, which are essential for executing apoptosis. These findings suggest that *Spermacoce latifolia* may serve as a promising natural source of anticancer agents[61,32].

### Wound Healing Properties

*Spermacoce latifolia* is traditionally used for its wound healing properties, which have been supported by scientific studies. The plant's extracts promote the healing of wounds by enhancing collagen synthesis, increasing wound contraction, and reducing the time required for wound closure[12,9]. The presence of antioxidant and anti-inflammatory compounds in the plant aids in mitigating oxidative stress and inflammation at the wound site, facilitating faster recovery. Additionally, the antimicrobial properties of *Spermacoce latifolia* help prevent infections, further supporting its use in wound management[62].

### Pharmacological Properties of *Celastrus paniculatus*

*Celastrus paniculatus*, known as the intellect tree or Jyotishmati, is a climbing shrub widely used in traditional Indian medicine. Modern scientific research has validated many of its traditional uses, revealing a range of pharmacological properties[63].

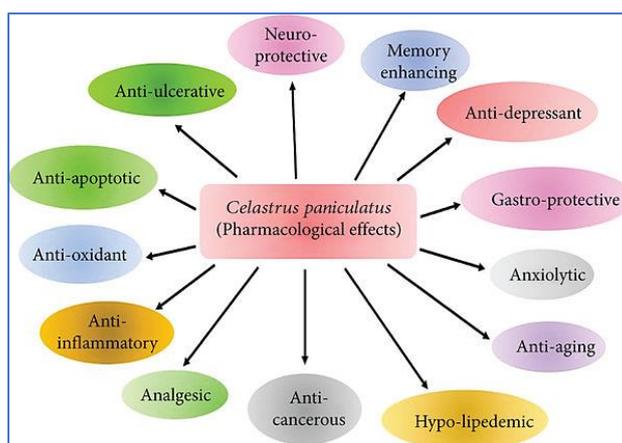


Figure 3: Pharmacological Properties of *Celastrus paniculatus*

### Neuroprotective Effects

*Celastrus paniculatus* has gained significant attention for its neuroprotective effects. The seeds of the plant contain bioactive compounds like celastrol and paniculatin, which are believed to confer these benefits[36]. Neuroprotection refers to the preservation of neuronal structure and function in the face of neurodegenerative conditions such as Alzheimer's disease, Parkinson's disease, and stroke. Studies have shown that extracts from *Celastrus paniculatus* can reduce oxidative stress and inflammation in the brain, both of which are key contributors to neuronal damage[33,9]. These effects are mediated through the modulation of various signaling pathways that protect neurons from apoptosis (programmed cell death) and enhance their survival and function[64].

### Memory-Enhancing Properties

One of the most celebrated traditional uses of *Celastrus paniculatus* is its memory-enhancing properties. In Ayurvedic medicine, it is classified as a "Medhya Rasayana," meaning a brain tonic. Modern research supports this traditional use, showing that the plant's extracts can

significantly improve learning and memory[3,9]. Animal studies have demonstrated that *Celastrus paniculatus* enhances cognitive performance in various tasks, likely due to its ability to enhance cholinergic function in the brain[19]. The seeds are rich in alkaloids and triterpenoids, which are thought to increase acetylcholine levels, a neurotransmitter crucial for learning and memory. This has prompted further research into its potential as a natural therapeutic agent for cognitive impairments and neurodegenerative diseases[65].

### **Anti-inflammatory Effects**

Inflammation plays a pivotal role in numerous chronic ailments such as arthritis, cardiovascular diseases, and neurodegenerative disorders. *Celastrus paniculatus* is noted for its notable anti-inflammatory effects[66]. The plant's bioactive components, particularly celastrol, have been observed to suppress the production of pro-inflammatory cytokines and diminish the activity of inflammatory enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX)[34]. These effects help in reducing inflammation and pain. Traditional uses of *Celastrus paniculatus* for conditions like arthritis and rheumatism are thus supported by these findings, making it a valuable plant in the management of inflammatory diseases[67].

### **Antioxidant Activity**

Oxidative stress, caused by an imbalance between free radicals and antioxidants, is linked to aging and various diseases like cancer and neurodegenerative disorders. *Celastrus paniculatus* demonstrates potent antioxidant properties due to its abundance of polyphenolic compounds, flavonoids, and triterpenoids[68]. These substances effectively neutralize free radicals and shield cells from oxidative harm. Research indicates that extracts from *Celastrus paniculatus* can significantly enhance the activity of natural antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase[19]. This antioxidant capability not only aids in preventing cellular damage but also reduces the risk of chronic diseases associated with oxidative stress[69].

### **Anti-diabetic Potential**

*Celastrus paniculatus* is being explored for its potential in managing diabetes mellitus, a condition characterized by elevated blood sugar levels due to insulin resistance or inadequate insulin production[16]. Studies have suggested that extracts from *Celastrus paniculatus* can effectively reduce blood glucose levels and enhance insulin sensitivity[70]. These effects are achieved through several mechanisms, including the inhibition of enzymes involved in carbohydrate digestion such as  $\alpha$ -amylase and  $\alpha$ -glucosidase, improved uptake of glucose by cells, and protection of pancreatic  $\beta$ -cells from damage caused by oxidative stress[18]. Together, these actions contribute to better control of blood sugar levels and propose that *Celastrus paniculatus* may serve as a beneficial adjunct in diabetes management[71].

### **Other Relevant Pharmacological Activities**

In addition to the aforementioned properties, *Celastrus paniculatus* exhibits a range of other pharmacological activities[27]. It has shown potential as an anxiolytic (anti-anxiety) agent, providing relief from stress and anxiety without the side effects associated with conventional medications. Its antimicrobial properties make it effective against various bacterial and fungal infections[72]. The plant also displays hepatoprotective effects, protecting the liver from toxic damage and enhancing its regenerative capacity. Furthermore, *Celastrus paniculatus* has been investigated for its potential anticancer properties, with studies indicating that its extracts can inhibit the growth of certain cancer cells and induce apoptosis[28].

## Pharmacological Mechanisms

Understanding the pharmacological mechanisms of medicinal plants like *Spermacoce latifolia* and *Celastrus paniculatus* is crucial for validating their traditional uses and potential therapeutic applications[32].

### Molecular Mechanisms Underlying the Pharmacological Activities of *Spermacoce latifolia*

#### 1. Anti-inflammatory Mechanisms

The anti-inflammatory properties of *Spermacoce latifolia* work by blocking key pathways involved in inflammation. Bioactive compounds such as flavonoids and alkaloids inhibit the production of pro-inflammatory cytokines such as TNF- $\alpha$  and IL-1 $\beta$ , and also reduce the activity of enzymes like cyclooxygenase-2 (COX-2) and lipoxygenase (LOX)[53,37]. These actions lead to a decrease in the production of inflammatory molecules like prostaglandins and leukotrienes. Additionally, these compounds hinder the nuclear factor-kappa B (NF- $\kappa$ B) signaling pathway, which is a critical regulator of inflammation[73].

#### 2. Antimicrobial Activity

*Spermacoce latifolia* exhibits significant antimicrobial properties against a variety of pathogens[21]. The antimicrobial action is primarily attributed to its alkaloids and phenolic compounds, which disrupt microbial cell walls and membranes, leading to cell lysis and death. These compounds also inhibit microbial enzymes and interfere with essential processes such as DNA replication and protein synthesis[55].

#### 3. Antioxidant Mechanisms

*Spermacoce latifolia* exhibits strong antioxidant properties due to its abundance of flavonoids and phenolic compounds[19,4]. These substances effectively neutralize harmful free radicals like superoxide anions and hydroxyl radicals, protecting cellular components such as DNA, proteins, and lipids from oxidative damage. Additionally, they stimulate the activity of natural antioxidant enzymes within the body, including superoxide dismutase (SOD), catalase, and glutathione peroxidase, enhancing the body's ability to counteract oxidative stress[74].

#### 4. Neuroprotective Effects

*Spermacoce latifolia* provides neuroprotective benefits through various mechanisms. Its bioactive components help prevent neuronal cell death by influencing the levels of apoptosis-related proteins like Bcl-2 and Bax. Moreover, these compounds decrease oxidative stress and inflammation in the brain, which are significant factors in neurodegenerative conditions[22,54]. Additionally, they enhance cholinergic activity by blocking acetylcholinesterase (AChE), the enzyme that breaks down acetylcholine. This action can potentially enhance cognitive function and memory retention[75].

#### 5. Anti-diabetic Mechanisms

The anti-diabetic potential of *Spermacoce latifolia* involves the modulation of key metabolic pathways[19,33]. The plant's compounds inhibit enzymes such as  $\alpha$ -amylase and  $\alpha$ -glucosidase, which are involved in carbohydrate digestion, leading to reduced postprandial blood glucose levels. They also enhance insulin sensitivity and promote glucose uptake by cells through the activation of insulin signaling pathways, including the PI3K/Akt pathway[76].

### Molecular Mechanisms Underlying the Pharmacological Activities of *Celastrus paniculatus*

### 1. Neuroprotective Mechanisms

*Celastrus paniculatus* exerts its neuroprotective effects through the modulation of several molecular pathways. Key compounds like celastrol and paniculatin reduce oxidative stress in neurons by enhancing the expression and activity of antioxidant enzymes[6,19]. They also inhibit pro-apoptotic signaling pathways and upregulate neurotrophic factors (e.g., BDNF) that support neuronal survival and function. Furthermore, these compounds modulate neurotransmitter systems, particularly the cholinergic system, enhancing synaptic plasticity and cognitive function[32].

### 2. Memory-Enhancing Mechanisms

The memory-enhancing properties of *Celastrus paniculatus* are largely attributed to its influence on cholinergic neurotransmission[12]. The plant's alkaloids inhibit acetylcholinesterase, thereby increasing the levels of acetylcholine in the brain, which is crucial for learning and memory. Additionally, these compounds modulate NMDA receptors, which play a key role in synaptic plasticity and long-term potentiation (LTP), fundamental processes for memory formation[77].

### 3. Anti-inflammatory Mechanisms

*Celastrus paniculatus* demonstrates potent anti-inflammatory properties by targeting inflammatory mediators and pathways[43]. Compounds such as celastrol inhibit NF- $\kappa$ B activation, a critical transcription factor that regulates the expression of pro-inflammatory genes. Additionally, these compounds suppress the production of inflammatory cytokines and enzymes like COX-2 and iNOS, thereby decreasing the synthesis of inflammatory prostaglandins and nitric oxide[51].

### 4. Antioxidant Mechanisms

The antioxidant activity of *Celastrus paniculatus* is driven by its high content of polyphenols and triterpenoids[35]. These compounds neutralize free radicals and enhance the antioxidant defense system by upregulating the expression of endogenous antioxidant enzymes. They also protect mitochondrial function, which is crucial for cellular energy production and reducing oxidative stress[78].

### 5. Anti-diabetic Mechanisms

*Celastrus paniculatus* exhibits anti-diabetic effects through multiple pathways. Its bioactive compounds inhibit carbohydrate-digesting enzymes like  $\alpha$ -amylase and  $\alpha$ -glucosidase, reducing glucose absorption in the intestine[18]. They also enhance insulin sensitivity and promote glucose uptake in peripheral tissues by modulating insulin signaling pathways, such as the PI3K/Akt pathway. Additionally, these compounds protect pancreatic  $\beta$ -cells from oxidative stress, preserving their function and insulin production[79].

### Safety and Toxicity

The safety and toxicity profiles of medicinal plants are critical factors that determine their therapeutic potential and acceptability. While *Spermacoce latifolia* and *Celastrus paniculatus* have been used traditionally for centuries, modern scientific evaluations are necessary to confirm their safety and identify any potential risks[20].

#### Safety Profile of *Spermacoce latifolia*

##### 1. Traditional Usage and Anecdotal Evidence

*Spermacoce latifolia* has been extensively used in traditional medicine across various cultures for its anti-inflammatory, antimicrobial, and other health-promoting properties. Anecdotal

evidence and historical usage suggest that the plant is generally well-tolerated when used in traditional therapeutic dosages[80].

## 2. Preclinical Studies

Preclinical studies involving animal models have provided valuable insights into the safety profile of *Spermacoce latifolia*. Acute toxicity studies typically involve administering high doses of the plant extract to animals to observe any immediate adverse effects[50]. In such studies, *Spermacoce latifolia* has shown a relatively high margin of safety, with no significant toxic effects observed at doses commonly used in traditional medicine[19,8]. Sub-chronic and chronic toxicity studies, which involve repeated administration of the extract over a longer period, have also indicated a favorable safety profile, with no major organ toxicity or adverse effects reported[29,45].

## 3. Human Studies

Limited human studies are available on the safety of *Spermacoce latifolia*. However, traditional use suggests a low incidence of adverse effects when the plant is used appropriately. The lack of reported serious side effects in historical and ethnobotanical records supports its general safety[34].

### Safety Profile of *Celastrus paniculatus*

#### 1. Traditional Usage and Anecdotal Evidence

*Celastrus paniculatus*, known for its cognitive-enhancing properties, has been used in traditional medicine, particularly in Ayurveda, for centuries. Its use as a memory enhancer and neuroprotective agent is well-documented, and historical evidence suggests it is safe when used in traditional dosages[81].

#### 2. Preclinical Studies

Animal studies have provided substantial data on the safety of *Celastrus paniculatus*. Acute toxicity studies have shown that the plant extract has a high LD50 (lethal dose for 50% of the population), indicating low acute toxicity[28]. Chronic administration studies have also demonstrated a good safety profile, with no significant toxic effects observed in vital organs such as the liver, kidneys, and heart. These studies suggest that *Celastrus paniculatus* is safe for long-term use at traditionally used dosages[82].

#### 3. Human Studies

Human clinical trials on *Celastrus paniculatus* are limited but have generally reported positive outcomes without significant adverse effects. Most reported side effects are mild and transient, including gastrointestinal discomfort or mild headaches, which are manageable and resolve without intervention[49].

### Toxicological Considerations and Potential Side Effects

#### 1. Dosage and Administration

The safety of both *Spermacoce latifolia* and *Celastrus paniculatus* is closely related to the dosage and method of administration. While traditional dosages are generally safe, exceeding recommended amounts can lead to adverse effects. It is crucial to adhere to traditional or clinically validated dosages to avoid potential toxicity[83].

#### 2. Potential Side Effects

*Spermacoce latifolia*: Potential side effects are rare but may include mild gastrointestinal upset, allergic reactions, or skin irritation when applied topically. These effects are generally

mild and resolve upon discontinuation of use[35].

***Celastrus paniculatus***: Possible side effects include mild gastrointestinal discomfort, nausea, or headache. These are usually transient and not severe. Some individuals may experience allergic reactions, though these are uncommon[44].

### 3. Drug Interactions

Both plants may interact with conventional medications, although specific interactions have not been extensively studied[19,8]. For instance, the anti-inflammatory properties of *Spermacoce latifolia* might potentiate the effects of other anti-inflammatory drugs, potentially increasing the risk of gastrointestinal irritation or bleeding. Similarly, the cognitive-enhancing effects of *Celastrus paniculatus* could interact with other nootropic or psychoactive medications, possibly leading to overstimulation or other neurological effects[84].

### 4. Special Populations

Special populations, including pregnant or breastfeeding women, children, and individuals with existing health conditions, should approach the use of these plants cautiously. There is limited information regarding the safety of these plants for such groups, therefore it is recommended to seek advice from healthcare professionals before using them[85].

### 5. Long-Term Safety

While traditional use supports the safety of these plants, long-term clinical studies are necessary to confirm their safety over extended periods[55,3]. Chronic toxicity studies in humans would provide more comprehensive data on potential cumulative effects and long-term safety[86].

### Conclusion

*Spermacoce latifolia* and *Celastrus paniculatus* are medicinal plants with rich ethnobotanical histories and diverse pharmacological properties. *Spermacoce latifolia* is valued for its anti-inflammatory, antimicrobial, antioxidant, neuroprotective, and anti-diabetic effects, largely mediated by its flavonoids, alkaloids, and phenolic compounds. *Celastrus paniculatus*, renowned for its neuroprotective and memory-enhancing properties, also exhibits anti-inflammatory, antioxidant, and anti-diabetic activities, with key bioactive compounds such as celastrene and paniculatine playing pivotal roles. Both plants have shown favorable safety profiles in preclinical studies, indicating low toxicity at traditional dosages. However, the limited human clinical data underscores the need for further research to confirm their safety and efficacy, especially for long-term use and in special populations. Potential side effects are generally mild and transient, but adherence to traditional dosages and consultation with healthcare professionals are recommended to mitigate risks. Overall, these plants hold significant promise as therapeutic agents, warranting continued scientific exploration to fully harness their medicinal potential while ensuring safety and efficacy.

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All authors contributed equally.

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