

A Review on Thuja Plant Species

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ABSTRACT

Thuja occidentalis, also referred to as Arborvitae or Northern White Cedar, is a significant conifer native to eastern North America. Historically valued for its medicinal properties, it was first utilized by Indigenous peoples to treat scurvy during the 16th century. In traditional medicine, Thuja has been used for various ailments, including respiratory infections, urinary disorders, and skin conditions. In modern applications, it is predominantly utilized in homeopathy and combined with other immunomodulating plants for treating upper respiratory infections. Despite its ecological importance and medicinal applications, there exists a gap in contemporary literature regarding its pharmacological properties and therapeutic efficacy. This review aims to provide a comprehensive, evidence-based overview of *Thuja occidentalis*, encompassing its botanical characteristics, phytochemistry, and pharmacological properties. We discuss its role in treating infections, its chemical constituents such as essential oils and flavonoids, and its antimicrobial, antioxidant, and anti-inflammatory effects. Furthermore, the review addresses the ecological challenges facing northern white cedar populations and emphasizes the need for informed management practices. By synthesizing current knowledge, this article serves as a vital source for researchers and practitioners interested in the applications and conservation of *Thuja occidentalis*.

Keywords: *Thuja occidentalis*, Northern White Cedar, Medicinal properties, Traditional medicines, Respiratory Infection, Urinary Disorder, Skin Condition, Homeopathy, Immunomodulating, Pharmacological Properties, Chemical Constituents, Essential Oils, Flavonoids, Antimicrobial, Anti-inflammatory

INTRODUCTION

Thuja occidentalis, also referred to as Arborvitae or white cedar, is indigenous to eastern parts of North America, including areas of Canada and the northeastern United States. It was first recognized for its medicinal value during a 16th – century expedition when indigenous people in Canada used it to treat scurvy-induced weakness. In traditional medicine, *Thuja occidentalis* has been employed for a variety of ailments, including Chronic bronchial inflammation, Urinary incontinence, Low urinary tract infection, Chronic skin inflammation, uterine cancer, amenorrhea, and rheumatism.^[6] Today, Thuja is primarily utilized in homeopathy, either as a mother tincture or in diluted forms. Additionally, it is combined with other immunomodulating plants, such

as *Echinacea purpurea*, *Echinacea pallida*, and *Baptisia tinctoria*, as part of evidence-based phytotherapy for treating acute and chronic infections of the upper respiratory tract.^[9] It is also used as an adjunct therapy with antibiotics in severe bacterial infections, including bronchitis, angina, pharyngitis, otitis media, and sinusitis. While several monographs and reviews cover the botany, constituents, pharmacology, and uses of Thuja in treating common colds, many of these works are outdated or in German. Therefore, we have aimed to present an updated, comprehensive, and evidence-based review of *Thuja occidentalis*, including its botanical characteristics, phytochemistry, in vitro and in vivo study, safety, and efficacy.^[11]

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Fig 1: *Thuja occidentalis*

HISTORY

The passage provides a detailed account of the ecological and management challenges facing northern white-cedar (*Thuja occidentalis*), a common conifer in southeastern Canada and northeastern United States. Despite its abundance, northern white-cedar has often been underrepresented in forestry literature, leading to uninformed management decisions. In Maine, it is the fourth most abundant conifer, after red spruce, eastern white pine, and

balsam fir. A key issue highlighted is the decline in northern white-cedar forestland in Maine, with a 7% decrease in forest area and an 8% decrease in growing stock volume between 1982 and 2003. However, saw-timber growing stock volume increased during this period. The species faces challenges such as slow early growth rates and competition in mixed stands, particularly because it is highly palatable to deer. Recruitment has also been a challenge, with limited sapling and pole timber recruitment observed, as seen in studies from the Big Reed Forest Preserve^[2]

ORIGIN

Thuja, the plant from which the homeopathic drug derived, belongs to the homeopathic drug is derived, belongs to the cypress family (Cupressaceae). Several species of the *Thuja* are known, and while *Thuja occidentalis* is the most commonly used species in homeopathy, other species also exist. Here are few Species of genus *Thuja* and *Platycladus* and their geographical distribution^[7]

Table no 1- Geographical Distribution

Species	Botanical origin	Geographical Distribution
<i>Thuja occidentalis</i>	Arborvitae, White cedar	North America & Europe
<i>Thuja Koraiensis</i>	Korean Thuja	North and South Korea, Changbai Mountain area of China, adjacent regions of the Sichuan province in China
<i>Thuja plicata</i>	Western Red Cedar	USA: Alaska, Montana, Washington, Oregon, California; Canada: British Columbia
<i>Thuja standishii</i>	Japanese Thuja	Japan
<i>Thuja sutchuenensis</i>	Sichuan Thuja	Northwestern China, Sichuan Province
<i>Thuja orientalis</i>	Oriental Thuja	China, Korea, Mongolia, and parts of Japan

Plant Profile

Taxonomical Classification

Table 2: Taxonomical Classification

Kingdom	Plantae
Division	Coniferophyte
Class	Pinopsida
Order	Pinales
Family	Cupressaceae
Genus	<i>Platycladus</i>
Specific Epithet	<i>Occidentalis</i>
Botanical Name	<i>Thuja occidentalis</i>

General Characteristics

Thuja occidentalis, commonly referred to as Northern White Cedar, has several distinct characteristics:

- **Appearance:** This evergreen tree can grow between 30 to 50 feet tall and 10 to 20 feet wide.

It has narrow, pyramidal like structure and dense, scale-like foliage.

- **Foliage:** The leaves are flat and scale-like, with a rich green color that can turn a warm bronze in winter. They are placed in alternate pairs along the stems.

- **Bark:** A reddish-brown color characterizes the bark and fibrous, peeling in long strips as it matures.
- **Cones:** Thuja occidentalis produces small, round cones that are about 0.5 inches long, which mature to a brown color.
- **Habitat:** It thrives in a variety of soil types but prefers moist, well-drained conditions. It's commonly found in wetlands and along riverbanks in its native range.
- **Hardiness:** This species is hardy in USDA zones 3 to 7, making it suitable for a wide range of climates.
- **Uses:** It's often used for hedges, windbreaks, and ornamental landscaping due to its dense growth habit. The wood is also valued for its decay resistance and is used in construction and fencing.

Special Characteristics

Here are some special characteristics of Thuja occidentalis:

1. Physical characteristics

- Height: 20-60 Feet
- Spread: 10-15 Feet
- Color: Reddish-Brown
- Shape: conical
- Male cones round yellow (4-8mm long), female cone ovoid, purplish.

2. Chemical characteristics

- Essential oil (thujone, bornyl acetate, terpinyl acetate)
- Flavonoids
- Phenolic acids

3. Pharmacological characteristics

- Antimicrobial (bacterial, fungal, viral)
- Antioxidant
- Anti-inflammatory
- Anticancer

- Antidiabetic

4. Identification characteristics

- Twigs: Yellow-Green, Slender flat, arranged in fern like sprays
- Winter Buds: small, uncovered, minute
- Pollen cones: yellowish with black scales, at the ends of new shoots, visible in April- may
- Seed cones: Small, oblong, reddish with 8-12 seed scales, appear in April- May, ripen by early autumn
- Wood: Light, Soft, brittle, straight-grained, durable, fragrant, pale yellow-bro

Vernacular Names

- Hindi: Morpankhi.
- Marathi: Thuja, Morpankhi
- English: Thuja orientalis, Tree of life
- Trade name: Chinese arborvitae
- French: Thuya oriental, Thuya De chine
- Italian: Tuiaorientale
- German: Morgenlaendischer Lebensbaum
- Spanish: Uya De La China

Morphology Plant

Leaves

- Colour: Initially light green to yellow-green, transitioning to brown after 3-4 years
- Shape: Scale-like, arranged in opposite-decussate pairs, and persistent

Flowers

- Ornamental value: Not significant
- Reproductive Type: Monoecious (both female and male reproductive organs present)

Fruit

- When Immature: Fleshy and blue-green with a glaucous appearance
- When Mature: Woody, cone-shaped, horn-like, and medium brown



TREE



SEED

Fig 2: *Thuja occidentalis* (a) Tree, (b) Seed

Description

Attractive foliage and bush-like growth habit. It is also commonly grown as hedge plant in cooler, moist regions, including India. Thuja is a slow-growing tree that can reach heights of 25 to 40 feet and spreads approximately 10 to 12 feet wide. It thrives in wet moist, nutrient-rich soils. Transplanting can be done moderately well, particularly if the plant is root-pruned and either balled and burlapped or potted. Thuja, also known as white cedar, is resilient in harsher climates, tolerating high humidity, wet soils, and even some drought conditions. During winter, its foliage tends to turn brown, especially in colored cultivars or in exposed areas with strong winds. The leaves, initially needle-like during their first year (1-10mm in length), later develop into scale-like structures arranged in alternating decussate pairs along the lateral sides of the twigs. Thuja flowers are monoecious, meaning that both female and male reproductive structures exist on the same plant, but on separate twigs or branchlets. Pollinated by wind, the male cones are rounded and reddish-yellow, while female cones are small, green, or purple-tinged. The mature cones are solitary, egg-shaped or oblong, measuring 8 to 16 millimeters long, with 4 to 6 pairs of versatile, thin scales. The seeds are flattened, ovoid, and typically 5-7 millimeters long and wingless. Thuja is widely cultivated for ornamental purpose^[13]

Botany

The five species of thuja are-

- *Thuja Koraiensis*- Korean Arborvitae
- *Thuja occidentalis*- Eastern White Cedar, Northern White Cedar

- *Thuja plicata*- Western Red Cedar
- *Thuja standishii*- Japanese Arborvitae
- *Thuja sutchuenensis*- Sichuan Arborvitae

Thuja Koraiensis

The tree of life is a common name for certain species of coniferous or evergreen shrubs belonging to the genus *Thuja*, part of the cypress family (William and Jackson, 1967). Rich in vitamin C, Thuja leaves were historically used by Native Americans and early European settlers to prevent and treat scurvy. They were also used to alleviate rheumatism. This plant is often associated with treating conditions like human papillomavirus (HPV), genital warts, and other skin ailments. It can grow between 3 to 10 meters in height, with flattened sprays of foliage. The leaves measure 2 to 4 mm (up to 15mm on particularly robust shoots), dark green on top, with pale waxy stripes underneath. The cones are oval, starting yellow-green, ripening to a reddish-brown, measuring 7 to 11 mm in length and 4 to 5 mm in width (occasionally up to 6-9 mm), and composed of 8 to 12 overlapping scales.^[3]



Fig 3: *Thuja Koraiensis*

Thuja Occidentalis

Thuja occidentalis, referred to as Northern white-cedar or arborvitae, is a coniferous tree that grows up to 38 meters tall but may be stunted in harsh climates.

It has reddish-brown or gray, fibrous bark and yellow-green, scale-like leaves. The tree can sometimes have multiple stems and produces red, ellipsoidal pollen cones that turn brown when mature.^[3]



Fig 4 :Thuja occidentalis

Thuja Plicata

Thuja plicata, also known as western white cedar, Western red cedar, or shingle wood, is not a true cedar (cedrus genus). It is one of the largest trees in the Pacific Northwest, often growing alongside Douglas-fir and western hemlock. This species thrives at elevations from sea level to 2,290 m (7,510 ft), such as at Crater Lake in Oregon. In addition to mountainous and forested areas, western red grows in wetland environments, like marshes and stream banks. It highly shade-tolerant and can regenerate under dense canopies. The tree has been introduced to various temperature regions, including Europe, Australia, New Zealand, the eastern U.S., and hawala. Thuja plicata can reach heights of 65 to 70 m (213 to 230 ft) with trunk diameters of 3 to 7 m (9.8 to 23 ft). when grow in open areas, the tree has a full crown, while in denser forests, the crown is limited to the top where sunlight is available. ^[3]



Fig 5: Thuja plicata

Thuja Standishii

Thuja standishii, also known as Japanese thuja, nezuko, or Kurobe, is a tree species native to southern Japan, primarily found on the islands of Honshu and shikoku. It reaches heights of 20-35 meters, with a trunk diameter of up to 1 meter. Its foliage consists of flat sprays with scale-like leaves, 2-4 mm long, matte

green on top, and featuring narrow white stomatal bands on the underside. The cones are oval, initially yellow-green, turning reddish-brown as they mature, measuring 6-12 mm in length and 4-5 mm in width, expanding to 8 mm when open, and are made up of 6-10 overlapping scales. The species is valued for its durable, waterproof, and pleasantly aromatic wood, making it an important timber tree in Japan, where it is cultivated in forestry plantations. Studies have found that extracts from T. standishii contain bioactive compounds, including standishii, which has been shown to have a strong inhibitory effect on the enzyme aromatase. This action reduces the production of estradiol in the body, making it a potential aromatase inhibitor.^[3]



Fig 6: Thuja standishii

Thuja Sutchuenensis

Thuja sutchuenensis, commonly known as the Sichuan thuja, is an evergreen coniferous tree belonging to the cypress family (Cupressaceae). It is native to China, specifically endemic to Cheng Kou County on the southern slopes of the Daba Mountains. This tree is either small or medium in size, potentially reaching heights of up to 20 meters, although no specimens of this size are currently known. Its foliage is arranged in flat sprays, with scale-like leaves that are 1.5-4mm long, green on top, and have narrow white stomatal bands underneath. The cones are oval, initially green, turning brown as they mature, measuring 5-8 mm long and 3-4.2 mm wide (opening up to 7 mm wide), with 8-10 overlapping scales. ^[3]



Fig 7: Thuja sutchuenensis

Ecology

Thuja occidentalis, or Eastern White Cedar, is native to eastern North America, ranging from Canada to North Carolina and Tennessee. It thrives in moist, well drained soils derived from calcareous bedrock (Anderson et al., 2019). This tree prefers alkaline soils with high calcium content, making it well-suited to its native habitat. Eastern White Cedar plays a significant ecological role in its native habitat. Its dense canopy provides shade, influencing understory vegetation (Kershaw & Drapauer, 1990). As a late-successional species, *Thuja occidentalis* often dominates old-growth forests (Frelich et al., 1993). This tree tolerates a range of moisture levels but excels in areas with consistent moisture.^[41]

Chemical Constituents

The essential oils of *Thuja orientalis* are comprised of diverse bioactive compounds, including monoterpenes and sesquiterpenes, carbohydrates, phenols, alcohols, ethers, aldehydes, and ketones. Specifically, the plant's leaves contain flavonoids

(rhodoxanthin, amentoflavone, quercetin) and carotenoids, while its seeds yield fatty oil rich palmitic, stearic, and unsaturated acids. The heartwood features aromadendrin, taxifolin, and cedrol, among others. The fruit and leaf oils primarily consist of α -pinene, α -cedrol, 3-carene, and limonene. Notably, *Thuja orientalis* also contains thujone, a naturally occurring ketone and monoterpene existing in diastereomeric forms. These complex chemical constituents contribute to the plant medicinal and aromatic properties. *Thuja orientalis* is a treasure trove of bioactive compounds, boasting an impressive array of monoterpenes, including borneol, camphene, limonene, alpha-terpine, and terpinolene, as well as the ketone fenchone. Additionally, it contains phenolic acids such as p-coumaric acid, flavonoids like kaempferol, myricitrin, and quercitrin, and polyphenols, notably tannic acids. This diverse constellation of constituents contributes to the plant's medicinal properties, making it a valuable resource for traditional and pharmaceutical applications.^{[24][50]}

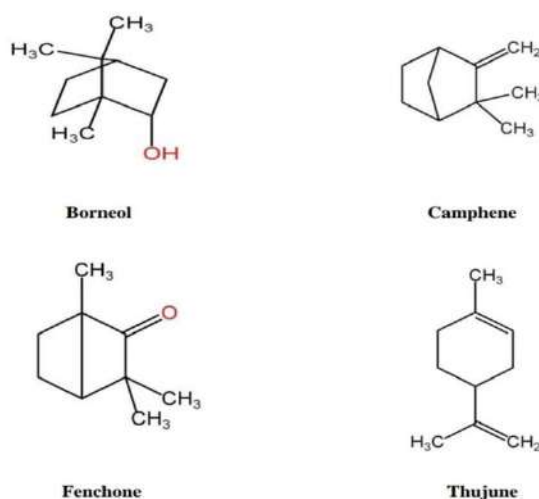


Fig 8: Structure of chemical Constituents

Pharmacological Activities

Anti-Microbial Activity

The antimicrobial properties of *Thuja occidentalis* and other plant extracts have been investigated, revealing significant activities against various microorganisms. *Thuja occidentalis*' alcoholic extract demonstrated antibacterial effects against both Gram-negative (*Pseudomonas aeruginosa*, *Yersinia aldovae*, *Citrobacter*, *Shigella flexneri* and *E. coli*) and Gram-positive (*Staphylococcus aureus*) bacteria. Similarly, *Vernonia anthelmintic*, *Dryopteris chrysocoma* and

Trachyspermum Ammi exhibited antibacterial and antifungal activities. In vitro studies confirmed their efficacy against six bacteria and six fungi, including *Escherichia coli*, *Staphylococcus aureus*, *Candida albicans* and *Aspergillus parasiticus*. However, a comparative study using 65% ethanol tinctures of *T. occidentalis* found activity only against *Staphylococcus aureus* and *Bacillus subtilis*. These findings support the potential use of these plant extracts in natural remedies and pharmaceutical

applications, warranting further research to explore their therapeutic potential.^{[4][5]}

Anti-Fungal Activity

Thuja occidentalis, a plant species, has demonstrated potent antimycotic and antifungal properties, making it a valuable natural remedy for combating fungal infections. Research conducted by Gupta and Srivastava in the early 2000s revealed its efficacy against *Aspergillus flavus* and *Aspergillus Niger*, two harmful fungi responsible for cutaneous aspergillosis and otomycosis, respectively. Further studies reinforced these findings, showcasing the plant's broad-spectrum antifungal activity against various strains, including *Candida albicans*, *Yersinia aldovae*, *Aspergillus parasiticus*, *Saccharomyces cerevisiae* and *Trichophyton rubrum*. The essential oil extracted from *Thuja occidentalis*' leaves and cones exhibited significant antibacterial and antifungal effects, validating its potential as a natural treatment for fungal diseases. Additionally, a 2018 study by Chinche et al. highlighted the plant's effectiveness against *Ashbya gossypii*, a fungus causing stigmatomycosis in cotton plants, underscoring its agricultural significance. By harnessing *Thuja occidentalis*' antimycotic properties, researchers aim to develop innovative, natural solutions for fungal infections, reducing reliance on synthetic antifungals. Its potential applications extend to agricultural sectors, where fungal diseases often result in substantial crop losses.^{[19][30]}

Anti-Cancer Activity

Researchers have discovered promising anti-cancer properties in *Thuja occidentalis*, specifically in its thujone-rich fraction (TRF). Traditionally, the crude ethanolic extract of *Thuja occidentalis*, known as homeopathic mother tincture (TOΦ), has been used to treat various ailments, including moles and tumors. Studies investigating TOΦ and TRF's anti-cancer potential focused on their effects on A375 melanoma cells. The results showed significant cytotoxic and anti-proliferative effects of both TOΦ and TRF on A375 cells. Notably, TRF exhibited enhanced anti-proliferative properties compared to TOΦ. Further analysis revealed that TRF induced apoptosis in A375 cells, characterized by DNA fragmentation, mitochondrial dysfunction, increased reactive oxygen species (ROS) production, cytochrome c release, and caspase-3 activation. Importantly, TRF demonstrated selectivity, with minimal growth inhibitory effects on

normal peripheral blood mononuclear cells. These findings provide scientific validation for the traditional use of *Thuja occidentalis* in treating tumors and moles. The thujone-rich fraction emerges as a key bioactive component responsible for the anti-cancer properties, warranting further investigation into its potential as a natural anti-cancer agent.^[46]

Anti-Viral and Immune-stimulant Activities

Thuja occidentalis, a plant species, boasts impressive antiviral and immune-boosting properties, thanks to its polysaccharides. Research has demonstrated its potential in combating HIV and influenza Type A viruses. A groundbreaking study by Gohla et al. in 1992 revealed that a high molecular weight Polysaccharide fraction from *Thuja occidentalis* effectively inhibited HIV-1 at a concentration of 625 µg/mL, remarkably without harming uninfected cells. Building on this discovery, subsequent research by Oliveira in 2010 uncovered additional benefits of homeopathic *Thuja occidentalis*. These include enhanced nitric oxide release, reduced superoxide anion production and increased bone marrow cell activity. Specifically, this involves elevated levels of CD3, CD45R and CD11 cells. These findings underscore *Thuja occidentalis*' potential as a natural antiviral agent and immune system supporter.^[34]

Anti-Gastric ulcer property

Thuja occidentalis has demonstrated remarkable anti-ulcer properties, providing protection against stomach ulceration induced by alcohol and aspirin. Research conducted by Deb et al. in 2009 revealed that ethanol and methanolic extracts of *T. occidentalis* significantly prevented stomach ulcers in rats. The study showed a substantial reduction in ulcer index and stomach acid secretion, with a 45% ($P < 0.05$) and 69% ($P < 0.001$) decrease observed at doses of 200 and 400 mg/kg, respectively. The plant's antioxidant properties contribute significantly to its anti-ulcer effects. Ethanol-induced stomach ulcers are characterized by reduced mucosal resistance, increased protein production in gastric juice and depleted glutathione levels in stomach mucosa. However, *T. occidentalis* extract has been shown to promote gastric epithelial regeneration, particularly at a dose of 400 mg/kg. These findings suggest that *Thuja occidentalis* may be a valuable natural remedy for preventing and treating stomach ulcers, warranting further investigation into its therapeutic potential.^[48]

Insecticidal Activity

A laboratory study assessed the insecticidal efficacy of deltamethrin, imidacloprid, thujone, and rosemary essential oil against sycamore lace bug (*Corythucha ciliata*) larvae and adults. The results revealed significant variations in mortality rates across the tested substances. Deltamethrin emerged as the most potent insecticide, inducing nearly 100% mortality in both developmental stages at all concentrations. Imidacloprid and rosemary essential oil followed, with the former causing 89.6% larval mortality at the recommended concentration and the latter resulting in 81.7% adult mortality at a 1% concentration. Notably, larvae proved more susceptible to the tested substances than adults. Mortality rates increased over time, ranging from 41.7% on day one to 71.3% on day three. The study suggests thujone and rosemary essential oil as environmentally friendly alternatives for controlling sycamore lace bug infestations on plane trees. These substances exhibited moderate insecticidal activity and repellent properties, potentially enhancing their effectiveness in open environments. Previous research has confirmed thujone's repellent effects, leading to significant mortality in western corn rootworm larvae due to acute poisoning.^{[44][45]}

Anti-HIV Activity

Research has demonstrated the potential anti-HIV properties of Thuja polysaccharides (TPS). Notably, TPS inhibited HIV-dependent cell death at a concentration of 625 µg/ml. Importantly, this concentration was found to be completely non-toxic to uninfected MT-4 cells. Further investigation revealed that TPS suppressed HIV-1-specific antigen expression on freshly infected MT-2 cells in a dose-dependent manner. This suggests that TPS may be a promising natural compound for HIV treatment or prevention.^{[20][9]}

Anti- Diabetic Activity

A study investigated the anti-diabetic properties of the ethanolic fraction of Thuja occidentalis (EFTO) and its underlying mechanisms. The research focused on alloxan-induced diabetes, examining fasting blood sugar levels, blood glutathione levels, and serum biochemical analysis. The results demonstrated that EFTO exhibited significant anti-diabetic activity at a dose of 200 mg/kg. Additionally, EFTO substantially increased blood glutathione levels, indicating its antioxidant properties (Dubey and Batra). This

suggests that EFTO's anti-diabetic effects may be partly attributed to its antioxidant activity.^[29]

Anti-pyretic Activity

Thuja demonstrates potent antipyretic properties, rivalling paracetamol's efficacy. Research revealed: *T. occidentalis* methanol extract (100-200 mg/kg) effectively regulated body temperature in rabbits. Comparable antipyretic effects to paracetamol against TAB (Typhoid) vaccination-induced fever. Oral doses (100-200 mg/kg) reduced fever and stabilized body temperature. Similar efficacy to aspirin in decreasing PGE1-induced pyrexia.^[30]

Neuroprotective Efficacy

A recent study explored the potential of Thuja occidentalis in alleviating diabetic neuropathy. Bhargava and colleagues induced diabetes in male Wistar rats using streptozotocin and nicotinamide. Subsequent treatment with Thuja occidentalis hydroalcoholic extracts significantly improved neuronal function and reduced oxidative stress and inflammation. This breakthrough suggests Thuja occidentalis may offer a natural solution for managing diabetic neuropathy, providing neuroprotection and mitigating associated complications.^[9]

Cardiovascular protective

A study investigated the hypolipidemic activity of the ethanolic fraction of Thuja occidentalis (EFTO) extract, derived from the aerial parts of the plant. The research assessed the effects of EFTO on lipid profiles in animals, administering doses of 200 mg/kg and 400 mg/kg body weight. The results demonstrated significant reductions in serum cholesterol (77% and 92%, respectively), LDL cholesterol (53% and 84%), and triglycerides (27% and 46%). Conversely, EFTO increased the HDL-to-total cholesterol ratio and decreased the atherogenic index, indicating its anti-atherosclerotic properties. The Thuja occidentalis extracts may be beneficial in managing hyperlipidaemia and reducing cardiovascular risk, highlighting its potential as a natural therapeutic agent.^[9]

CONCLUSION

The review on Thuja species highlights its significant pharmacological properties and potential therapeutic applications, positioning it as a promising medicinal plant. Thuja extracts, with their bioactive compounds, have shown various beneficial effects in health applications due to their safety and efficacy.

Traditionally, Thuja has been used in both culinary and therapeutic contexts, particularly for its essential oils and extracts in topical formulations. Recent studies have also explored its potential in cosmetics and natural product development, including hair and skincare products, demonstrating its versatility and expanding utility in herbal product innovation

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