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Review Paper

A Comprehensive Review of Araucaria Heterophylla

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ABSTRACT

An evergreen conifer in the family Araucariaceae, the Norfolk Island pine (Araucaria heterophylla) is significant from ecological, ornamental, cultural, and medicinal perspectives. This comprehensive analysis, which focuses on the bark, integrates the body of knowledge regarding its taxonomy, morphology, vernacular distribution, horticultural methods, ecological adaptation, and economic significance. The species is frequently grown outside of its natural habitat of Norfolk Island due to its ability to adapt to tropical and subtropical climates, tolerance to salinity, and aesthetic appeal. Botanical characteristics such as its symmetrical crown, needle-like evergreen foliage, and drought resistance are responsible for its horticultural significance. The distinctive macroscopic and microscopic features of A. heterophylla bark, such as fissured texture, resin ducts, and lignified tissues, are essential for pharmacogenetic identification and standardization. According to phytochemical analyses, bark-derived extracts like essential oils and gum exudates contain a variety of bioactive components, such as terpenoids, flavonoids, phenolics, alkaloids, lignans, resin acids, and volatile chemicals. Thanks to extraction techniques like hydro-distillation and gum separation, compounds like sesquiterpenes like cadinene, copaene, and germacrene have been characterized.

INTRODUCTION

The striking evergreen conifer *Araucaria heterophylla*, which is native to Norfolk Island, has captured the attention of botanists, horticulturists, and enthusiasts due to its exceptional qualities. This species has been a major part of botanical lore and cultural traditions due to its stately size, elegant foliage, and incredible tenacity[1]. Furthermore, in addition to its aesthetic value, *Araucaria heterophylla* is becoming more and more known for its therapeutic qualities, drawing interest and investigation in ethnobotanical research[2].

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Modern scientific studies have confirmed the traditional use of *Araucaria heterophylla* and shed light on the plant's chemical composition and therapeutic qualities. Araucaria heterophylla contains a variety of bioactive compounds, such as flavonoids, terpenes, and phenolic acids, that have antibacterial, anti-inflammatory, and antioxidant properties[3]**.** These compounds may be used to develop innovative drugs and nutraceuticals to treat a variety of conditions, including chronic inflammation, infectious diseases, and disorders linked to oxidative stress. *Araucaria heterophylla* has also gained attention for its use in traditional healing techniques and holistic wellness treatments, particularly in regions where it is grown or native [4]**.** Complementary and alternative medicine advocates, naturopaths, and herbalists incorporate extracts and formulations derived from *Araucaria heterophylla* into their practices, leveraging the plant's natural healing qualities to promote overall health and vitality.

The renewed significance of *Araucaria heterophylla* as a helpful tool for enhancing human health and holistic wellbeing is highlighted by the growing interest in botanicals and natural therapy supplements [5]. As scientific understanding of this remarkable species' medicinal properties grows, there is an urgent need to protect and sustainably manage its populations. The ecological and cultural heritage of this well-known tree depends on the conservation of *Araucaria heterophylla* habitats, ethical harvesting practices, and community-driven initiatives [6]. By combining traditional knowledge with contemporary scientific research, we can fully realize the therapeutic potential of *Araucaria heterophylla* and create new opportunities for healthcare and healing[7]**.**

Araucaria heterophylla, commonly known as the Norfolk Island pine, is a conifer belonging to the ancient family Araucariaceae. Its taxonomic classification is as follows[8]:

Table 1: Taxonomy of Araucaria heterophylla

Kingdom	**Plantae**
Division	**Pinophyte**
Class	**Pinopsida**
Order	**Pinales**
Family	**Araucariaceae**
Genus	***Araucaria***
Species	***heterophylla***

Fig.1 ***Araucaria heterophylla***

Table 2: Vernacular names of *Araucaria heterophylla*

Language	Vernacular name
English	Norfolk Island pine, Star pine, Triangle tree, Christmas tree
Hindi	Vilayati Saru, Vilayati devdar
Telugu	Norfolk Chettu
Kannada	Norfolk mara
Malayalam	Norfolk pine maram
Tamil	Kattai pine
Spanish	Pino de Norfolk,Pino de pisos
Japanese	Shima – Nanyosugi
Chinese	Nan Yang Shan
Dutch	Kamerden
Trade name	Ashok pine in West Bengal

Horticultural and Cultivation Methods

Araucaria heterophylla is widely grown as an ornamental tree due to its striking appearance, symmetrical growth habit, and ability to adapt to a range of environmental conditions. In addition to parks, gardens, and avenues, it is commonly planted as a visually pleasing indoor plant, particularly when it is young. The plant prefers sandy or loamy soils that drain well and thrives in full to partial shade [(9)]. The majority of *Araucaria heterophylla* is propagated by seeds, which should be sown in moist, well-aerated soil for optimal germination. Seedlings require frequent watering in the early stages of growth, but excessive moisture should be avoided to prevent root rot[(10)]. Vegetative propagation is less common because the tree reacts slowly to grafting and cutting methods. Regular care practices, such as pruning, are usually minimal because *Araucaria heterophylla* naturally produces a consistent and aesthetically pleasing structure[(11)].Its unique symmetrical shape may be broken by overpruning, so it should be avoided. There must be sufficient air circulation and room for crown development when planting a large number of trees. Although young plants require frequent watering to encourage healthy root growth, once established, the species can tolerate extreme drought. Fertilization with balanced nutrients can encourage growth, especially in nutrient-poor soils[(12)]. Because it is resistant to common pests and diseases, *Araucaria heterophylla* is also a low-maintenance choice for horticultural use. It is a popular choice for landscaping projects worldwide due to its adaptability and visual appeal. Its broad horticultural relevance is further enhanced by the fact that its evergreen leaves and vertical shape allow it to be used in both formal and informal landscape designs[(13)]**.**

Geographical details and Habitat

Araucaria heterophylla is native to Norfolk Island, a small island located in the South Pacific Ocean between Australia, New Zealand, and New Caledonia. Despite its limited natural distribution, *Araucaria heterophylla* has been widely cultivated and introduced to various regions around the world due to its ornamental value and adaptability to diverse climatic conditions [(14)]**.** The species thrives in subtropical and tropical climates, favoring coastal environments where it is exposed to high humidity, moderate rainfall, and well-drained soils. *Araucaria heterophylla* demonstrates a notable tolerance to saline conditions and strong winds, making it particularly well-suited for coastal landscaping and urban greening projects. Its ability to withstand harsh environmental conditions contributes significantly to its widespread cultivation beyond its native range. In its natural habitat, *Araucaria heterophylla*

typically grows on volcanic soils and limestone-derived substrates, which provide essential nutrients and adequate drainage[15]. The tree's extensive root system enables it to anchor firmly in shallow soils, enhancing stability against strong coastal winds. This adaptation is crucial for its survival in exposed island environments where soil depth and stability may be limited. Beyond Norfolk Island, *Araucaria heterophylla* has been successfully introduced and cultivated in regions including Southeast Asia, South America, Africa, and parts of the Mediterranean[16]**.** In these areas, it is commonly planted in gardens, parks, avenues, and institutional landscapes, where it serves as an ornamental focal point due to its symmetrical form and evergreen foliage. The ecological role of Araucaria *heterophylla* in introduced habitats varies depending on environmental conditions and management practices. While primarily valued for its aesthetic and cultural significance, the species also contributes to local ecosystems by providing shelter for birds and other fauna. However, careful monitoring is essential to prevent potential ecological imbalances associated with the introduction of non-native species[17]**.**

Economical value and Conservation

Araucaria heterophylla holds considerable economic importance due to its ornamental, cultural, and commercial value. The tree is widely cultivated for landscaping purposes in residential areas, public parks, institutional campuses, and coastal regions. Its symmetrical growth pattern and evergreen foliage make it a preferred choice for decorative planting, contributing significantly to the horticulture and nursery industries[18]. In addition to its ornamental value, *Araucaria heterophylla* has been utilized for timber production in limited contexts**.** The wood, although not extensively exploited, is known for its fine texture and workability, making it suitable for furniture, interior decoration, and light construction purposes. However, due to conservation concerns, the use of timber from this species is regulated in many regions[19]. The cultural significance of *Araucaria heterophylla* further enhances its economic value. In various parts of the world, the tree is associated with ceremonial, religious, and festive occasions, particularly during the Christmas season, where it is commonly used as a decorative indoor plant[20]**.** This cultural association has increased its demand in both local and international markets**.** Despite its widespread cultivation, *Araucaria heterophylla* faces conservation challenges in its native habitat. Habitat loss, climate change, and human activities pose potential threats to natural populations on Norfolk Island. Conservation strategies focusing on habitat protection, sustainable cultivation, and public awareness are essential to ensure the long-term survival of this species. Efforts to conserve *Araucaria heterophylla* involve collaboration between governmental agencies, conservation organizations, and local communities. By promoting sustainable practices and encouraging research on propagation and genetic diversity, these initiatives aim to balance economic utilization with ecological preservation[21]**.**

Botanical information

A detailed account of the botanical features is given in the table below[22] :

Table 3: Description of Araucaria heterophylla

Scientific name	***Araucaria heterophylla***
Pronunciation	Air-ah-KAIR-ee-uh het-er-oh-FILL-uh.
Common names	Norfolk pine
Family	Araucariaceae
Origin	Native to Norfolk Island

Applications	Perfect for growing indoors
Availability	Widely available
Height	60-80 feet
Spread	12-20 feet
Crown uniformity	The canopy is symmetrical and has a regular (or smooth) outline, and individuals have nearly identical crown forms.
Crown shape:	columnar or pyramidal
Crown density	Open
Growth rate	Quick
Roots	Surface roots may cause sidewalks to rise or obstruct mowing.
Trunk, bark, and branches	Should be grown with a single leader; thorn-free; grow mostly upright and not droop; not very showy. Pruning requirement: minimal. Clay, loam, sand, acidic, alkaline, and well-drained soils are all acceptable
Leaf	Leaf arrangement in a spiral. Leaf type: simple. Full leaf margin Leaf shape: filiform, needle-like, or straight. Leaf venation: parallel Persistence and leaf type: needle leaf evergreen, evergreen. Leaf blade length: less than two inches. The leaf's color is green. Fall color: no color shift. Fall characteristics: understated
Flowers	A blossom. Flowers' subtle and unobtrusive qualities.
Fruit	Fruit shape: oval. Fruit lengths range from 3 to 6 inches to 12 inches. Fruit covering: dry or firm. The fruit is green in color. Fruit characteristics include being ostentatious, not attracting wildlife, and creating a lot of litter from fruit and twigs.

An analysis of *Araucaria heterophylla* bark

An examination of the bark of *Araucaria heterophylla* (Salisb.) *Araucaria heterophylla.* The Araucariaceae family includes the Norfolk Island pine, also known as Franco. It is an evergreen ornamental conifer that is frequently found in tropical and subtropical regions. Although the majority of research has focused on leaves and oleoresin, new information suggests that materials made from bark, such as essential oils and gum exudates, contain physiologically active compounds that may find use in medicine. Natural products from conifers are recognized as important sources of bioactive terpenoids and phenolic compounds, which may have antioxidant, antibacterial, and cytotoxic effects[23].

Pharmacognostic details

Araucaria heterophylla, commonly known as the Norfolk Island pine, is renowned not only for its majestic stature and ornamental value but also for the diverse array of bioactive compounds present within its tissues. The phytochemistry of *Araucaria heterophylla* encompasses a rich repertoire of secondary metabolites, including terpenes, flavonoids, phenolic compounds, alkaloids, resin acids, lignans, fatty acids, and volatile compounds. These bioactive constituents contribute to the plant's resilience, ecological interactions, and potential medicinal properties, making Araucaria heterophylla a subject of interest for botanical research and pharmacological exploration[24]. Terpenes are ubiquitous in *Araucaria heterophylla*, where they contribute to the plant's distinctive aroma and may confer pharmacological benefits. These volatile compounds include mono- and sesquiterpenes, known for their antioxidant, antimicrobial, and anti-inflammatory activities. Similarly, flavonoids, another class of secondary metabolites found in *Araucaria heterophylla*, exhibit potent antioxidant and anti-inflammatory properties, which may contribute to the plant's defense mechanisms and potential health benefits.

Phenolic compounds, such as phenolic acids and tannins, are abundant in *Araucaria heterophylla* and possess antioxidant and antimicrobial properties. These compounds play a crucial role in protecting the plant against pathogens and environmental stressors, highlighting their importance in plant defense and adaptation [25].

Fig.2 Bark of *Araucaria heterophylla*

Moreover, alkaloids have been identified in *Araucaria heterophylla*, although their presence and significance may vary among different populations of the plant. Alkaloids are known for their pharmacological effects and may contribute to the plant's medicinal properties. Resin acids are another group of bioactive compounds found in *Araucaria heterophylla*, particularly in the resin obtained from the bark[26]. These resin acids exhibit antiseptic and wound-healing properties, making them valuable in traditional medicine and potentially applicable in modern pharmaceuticals. Lignans, polyphenolic compounds found in *Araucaria heterophylla*, demonstrate antioxidant and estrogenic activities, contributing to the plant's overall health benefits and therapeutic potential. *Araucaria heterophylla* seeds contain fatty acids, including omega-3 and omega-6 fatty acids, which are essential for human health [27]. These fatty acids play a crucial role in cardiovascular health, brain function, and inflammation regulation. Additionally, volatile organic compounds emitted by *Araucaria heterophylla* foliage contribute to the plant's aroma and may have ecological roles in attracting pollinators or deterring herbivores. The phytochemistry of *Araucaria heterophylla* reflects its adaptation to environmental challenges and its potential [28].

Morphology of Bark

Macroscopic Characteristics

Mature *Araucaria heterophylla* trees have thick, rough, longitudinally fissured bark. The exterior is grayish-brown to dark brown, while the interior is a little lighter. The bark of woody conifers gets scaly and heavily fractured as they get older. The presence of oleoresin ducts, which are typical of members of the Araucariaceae family, is suggested by the gritty texture and resinous exudation after incision[29].

Microscopic Characteristics

Despite the lack of comprehensive bark microscopy research, conifer bark architecture typically consists of the following: Cork (phellem) layers, Phellogen (cork cambium), Phelloderm, Secondary phloem, Resin ducts, Fibers, and Sclereids. Standard pharmacognostic descriptions

for coniferous bark state that lignified fibers and resin channels are present in phloem tissue[30].

Pharmacognostic Assessment of bark

Standardization in pharmacognostics is necessary for the authentication of crude drugs. Among the evaluation criteria are: Organoleptic Assessment, Grayish-brown Color, Rough and Fissured Texture, Mildly Resistant Odor, and Slightly Astringent Taste, Physical-Chemical Characteristics. The following are included in the evaluation of bark, per standard pharmacognostic procedures. Alcohol-soluble extractive value, water-soluble extractive value, total ash value, acid-insoluble ash, water-soluble ash, loss on drying, and foreign matter determination. These tests aid in identifying the crude bark drug's identity, quality, and purity [31] .

Fig.3 Collected fresh bark of *Araucaria heterophylla*

Methods of Extraction

Extracting Essential Oils

Essential oil has been extracted from the stem bark of *A. heterophylla* by hydrodistillation with a Clevenger apparatus. Yields reported: ~0.33% for fresh bark and ~0.29% for dried bark. For chemical profiling, GC-MS analysis was performed on the extracted oil[32].

Gum Extraction

Natural gum exudate from bark incisions has been collected, dried, and purified. Extraction processes include collecting exudate, drying it in the shade, powdering it, and purifying it with distilled water. Filtration and drying: The extracted gum is primarily composed of polysaccharides and may find application as a medicinal excipient [33] .

Phytochemical Constituents and Essential Oil Components

GC-MS analysis revealed that bark oil contained several sesquiterpenes and monoterpenes, such as oxygenated sesquiterpenes, γ-Cadinene, Copaene, Germacrene B, and pathulenol. The contribution of these terpenoids to biological activity is widely acknowledged[34].

Table 4: Chemical tests

S.No.	Tests	Inference
1.	Dragondroff's reagent	Alkaloids (Orange precipitate)
2.	Mayer's test	Alkaloids (cream color ppt.)
3.	Shinoda	Flavonoids (Pink/red coloration)
4.	Ferric chloride	Phenols (Blue-green color ($FeCl_3$)
5.	Foam	Saponins (stable foam)
6.	Salkowski test	Terpenoids (Reddish-brown ring)
7.	Liebermann-Burchard	Steroids (Green color)

These tests confirm the presence of major phytochemical groups[35].

Pharmacological activities of *Araucaria heterophylla*

The pharmacological potential of *Araucaria heterophylla* has been investigated in detail through review, in vitro, and in vivo studies. Plant parts that have demonstrated a range of biological activity include resin, leaves, and essential oils[36].

Anti-Inflammatory activities: The essential oil that was extracted from the resin of *Araucaria heterophylla* demonstrated significant anti-inflammatory qualities in experimental animal models. The reduction of paw edema and the suppression of pro-inflammatory cytokines by its nanoemulsion formulation validated the oil's therapeutic potential in inflammatory conditions [37].

Antipyretic activity: The resin essential oil and its nanoemulsion showed a strong antipyretic effect in animal studies by significantly reducing elevated body temperature. The activity was comparable to that of popular antipyretic drugs[38].

Antioxidant activity: Several studies found that *A. heterophylla* extracts, including resin, leaves, and aerial parts, had strong antioxidant activity. These effects were attributed to the presence of phenolics, flavonoids, and terpenoids, as shown by DPPH and other free radical scavenging tests [39].

Anticancer and cytotoxic properties: On a variety of human cancer cell lines, such as MCF-7, HepG2, HCT-116, and Caco-2, *A. heterophylla* resin extracts in ethanol and chloroform demonstrated potent anticancer and cytotoxic effects. Labdane monoterpenes and diterpenes were found to be the primary contributors to this activity[40].

Microbe-Repelling Action: Essential oils and extracts from *Araucaria heterophylla* have demonstrated broad-spectrum antibacterial efficacy against both Gram-positive and Gram-negative bacteria as well as certain fungal strains. Its historical use in medicine is validated[41].

Action Against Microorganisms: Essential oils and extracts from *Araucaria heterophylla* have demonstrated broad-spectrum antibacterial efficacy against both Gram-positive and Gram-negative bacteria as well as certain fungal strains. This activity supports its historical use in medicine[42].

Antiviral Properties: Metabolomic and in silico studies that indicated A. heterophylla may have antiviral activity and roles against viral targets underscored its importance in antiviral drug development research[43].

Antiulcer action: Review studies on the genus Araucaria showed antiulcer activity, which was attributed to *A. heterophylla's* cytoprotective and antioxidant properties[44].

Neuroprotective and Antidepressant Characteristics: Phytochemical components in *Araucaria heterophylla* have been associated with neuroprotective and antidepressant effects based on extensive research on the species[45].

Hypoglycemia Activity: Leaf extracts from *Araucaria heterophylla* have been demonstrated to have hypoglycemic action, which may aid in the treatment of diabetes mellitus[46].

Environmental activity: Significant environmental activity has been observed in the ability of Araucaria heterophylla leaf biomass to extract lead (Pb2+) from aqueous solutions. The study found that the biosorption process followed the Freundlich isotherm model and pseudo-second-order kinetics, with a maximum removal efficiency of 95.12% at pH 5. It was found that metal binding involved functional groups like –OH, C=O, and P=O, and that the process was

exothermic and spontaneous. These findings suggest that plant biomass can be employed as an inexpensive, effective, and environmentally friendly biosorbent to extract heavy metals from polluted water [47].

FUTURE PROSPECTS

It is important to look closely at A. heterophylla's genetic diversity and physiological adaptations. A species' ability to adapt and survive in the face of shifting climatic conditions can be greatly enhanced by researching genetic diversity among various populations and how they react to environmental stressors**.** These discoveries will aid in the creation of successful conservation initiatives that protect genetic resources and improve ecological stability in their natural and agricultural environments. Another important subject is the application of sustainable management techniques[48]. This entails creating scientifically guided methods for harvesting, cultivating, and multiplying in order to prevent overexploitation. By applying the ideas of agroforestry and sustainable forestry, utilization and regeneration can be balanced, maintaining ecosystem integrity and ensuring resource availability for future generations. Additionally, research into innovative growing techniques and the production of value-added products derived from *A. heterophylla* holds great promise[49]. Agroforestry models can promote economic sustainability and environmental responsibility by integrating this species with appropriate crops and creating bioproducts from its wood, resin, and other plant parts. These tactics have the potential to improve local communities' quality of life and diversify their sources of income. Raising public awareness of *A. heterophylla's* ecological and cultural significance is equally important. The expansion of ecotourism, community engagement programs, and educational initiatives may increase support for conservation and promote responsible stewardship among both locals and tourists. Strong cooperation between stakeholders, including governmental bodies, academic institutions, non-governmental organizations, and indigenous groups, is also necessary for effective conservation [50]**.** In order to implement comprehensive conservation strategies that address the ecological, social, and economic challenges associated with this species, interdisciplinary collaboration and knowledge sharing are essential. In conclusion, coordinated conservation efforts, sustainable resource management, and integrated research are essential to the long-term survival of *Araucaria heterophylla* [51]**.** It is feasible to protect this species and guarantee its continued ecological and economic significance for future generations through concerted efforts and ecologically conscious actions. Detailed microscopic characterization of bark isolation and structural elucidation of active compounds. In vivo pharmacological studies, clinical validation, and development of standardized herbal formulations. Natural products continue to be important sources of drug discovery, supporting further research on *A. heterophylla* bark [52]**.**

CONCLUSION

Araucaria heterophylla is a remarkable evergreen conifer with significant ecological, decorative, medicinal, and commercial value. Its distinctive shape, ability to adapt to a range of climatic conditions, and cultural significance have all contributed to its continued popularity and worldwide cultivation. From its original habitat on Norfolk Island to its current global presence in gardens, parks, and urban landscapes, it continues to play an important role in both natural and human-modified habitats. The growing body of research supporting the traditional medicinal uses highlights the plant's potential as a valuable source of bioactive compounds. Phytochemical and

pharmacological studies have demonstrated promising antioxidant, antibacterial, anti-inflammatory, and anticancer effects, underscoring the need for additional study and clinical validation. Combining traditional knowledge with modern scientific techniques may lead to the development of new plant-based medications. However, conservation of this plant remains a significant issue, particularly in its natural habitat. Increased public awareness, sustainable farming practices, and habitat preservation are essential to this species' long-term survival. By finding a balance between ecological responsibility and commercial use, *Araucaria heterophylla* can continue to benefit future generations while preserving its natural and cultural legacy.

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