**A Comprehensive Review of the Conservation Status and Ethnobotanical Significance of *Acorus calamus***

**Abstract**

***Acorus calamus***, commonly known as sweet flag, is a perennial herb of significant medicinal, aromatic, and ecological value, native to wetlands across Asia, Europe, and North America. The plant has a rich history of use in traditional medicine, where its aromatic rhizomes have been utilized for centuries to treat various ailments, including digestive disorders, respiratory conditions, and cognitive impairments. The essential oils extracted from its rhizomes contain bioactive compounds such as alpha-asarone, beta-asarone, and eugenol, which have demonstrated antimicrobial, anti-inflammatory, sedative, and neuroprotective properties. Ecologically, ***Acorus calamus*** plays a vital role in wetland habitats by stabilizing soil, filtering water, and providing a habitat for aquatic species, thus supporting the overall health of these ecosystems. However, the plant faces significant conservation challenges due to overharvesting, habitat loss, and climate change. Overharvesting driven by high demand in traditional medicine and the herbal industry has led to the depletion of wild populations, while habitat loss from wetland drainage, agricultural expansion, and urban development further threatens its survival. Climate change, with its impact on water levels and weather patterns, poses additional risks to the species' natural habitats. To ensure the sustainable use and conservation of ***Acorus calamus***, it is essential to implement effective conservation strategies, such as in-situ and ex-situ conservation, sustainable harvesting practices, and community-based conservation programs. These efforts are crucial to preserving this valuable species for its continued ecological benefits and potential in traditional and modern medicine.

**1. Introduction**

***Acorus calamus***, commonly known as sweet flag or calamus, is a perennial herbaceous plant belonging to the family Acoraceae. It is renowned for its distinctive aromatic rhizomes, which have been utilized for centuries in traditional medicinal systems such as Ayurveda, Traditional Chinese Medicine, and Native American practices (Singh et al., 2020). These rhizomes are rich in bioactive compounds, including alpha-asarone and beta-asarone, which are known for their therapeutic properties, including antimicrobial, anti-inflammatory, and cognitive-enhancing effects (Gupta & Nair, 2017). The plant is easily identifiable by its long, sword-shaped leaves that grow upright from a thick, creeping rhizome. The leaves are typically bright green and can grow up to 1 meter in length. The small, greenish-yellow flowers of **Acorus calamus** are arranged in a unique cylindrical spike, known as a spadix, which emerges from the base of the leaves (Choudhary et al., 2022). The plant’s morphological characteristics make it well-adapted to wetland environments, where it thrives in marshes, swamps, riverbanks, and lakeshores. It is commonly found in temperate and subtropical regions of Asia, Europe, and North America (Li et al., 2018).

***Acorus calamus*** plays a significant ecological role in its natural habitat. It helps stabilize soil and provides a habitat for various aquatic species, thereby contributing to the overall health of wetland ecosystems. Its ability to thrive in wet, marshy conditions also makes it a useful plant for phytoremediation, a process where plants are used to clean contaminated soil and water (Wang et al., 2019). Despite its ecological and medicinal significance, the wild populations of ***Acorus calamus*** are declining due to habitat loss, overharvesting, and climate change (Patel & Bhandari, 2020). *A. calamus* L. is a perennial herbaceous plant with rhizome that is indefinitely branched, smooth, pinkish or pale green, and widely distributed in China. Although *A. calamus* L. is a highly valued medicinal plant, it has been used for the removal of contaminants such as hexavalent chromium and divalent lead ions (Shooto, 2020), leachate (Bhagwat et al., 2018), microcystin-LR (Chen et al., 2019), and algae (Zhang et al., 2016).

The plant's extensive use in traditional medicine stems from its various pharmacological properties. Traditionally, ***Acorus calamus*** has been used to treat digestive disorders, respiratory ailments, cognitive dysfunctions, and anxiety. Its use as a natural insect repellent and in perfumery further underscores its versatility (Sharma et al., 2021). However, overharvesting of the wild populations for these uses, combined with habitat destruction and environmental pollution, has raised concerns about the sustainability of its wild stocks (Kumar & Kumar, 2019).

To ensure the sustainable management and conservation of ***Acorus calamus***, various strategies have been proposed, including in-situ conservation, ex-situ cultivation, and community-based conservation programs. These strategies aim to protect existing populations in the wild, preserve genetic diversity, and involve local communities in sustainable harvesting practices (Choudhary et al., 2022). Further research into the plant’s ecological roles, phytochemical properties, and sustainable cultivation practices is essential to develop effective conservation strategies and explore new therapeutic uses for this valuable plant (Singh & Meena, 2023).

**Importance of Study**

The importance of ***Acorus calamus*** is twofold. Ecologically, it plays a crucial role in maintaining the health of wetland ecosystems by stabilizing soil and providing habitat for various aquatic species. Its dense rhizome mat helps to prevent soil erosion, while its presence supports biodiversity by offering critical shelter and nourishment to aquatic and semi-aquatic organisms (Wang et al., 2019). The plant also contributes to phytoremediation by absorbing pollutants from the soil and water, further enhancing the health of its environment (Li et al., 2018).

Ethnobotanically, ***Acorus calamus*** is highly valued for its medicinal properties. It has been traditionally used to treat a range of ailments, including digestive disorders such as indigestion and bloating, respiratory conditions like coughs and bronchitis, and cognitive issues such as memory impairment. Additionally, it is known for its anxiolytic and sedative effects, which are beneficial for managing stress and anxiety (Sharma et al., 2021). Its use extends to various cultural practices, including rituals and ceremonies where its aromatic properties are utilized for purification and protection (Ray & Ghosh, 2021).

Despite its significance, ***Acorus calamus*** is facing challenges due to extensive use and overharvesting, particularly in regions where it is highly sought after for its medicinal and commercial value. Habitat destruction, climate change, and pollution further exacerbate the threats to its populations (Kumar & Kumar, 2019; Patel & Bhandari, 2020). Consequently, it is imperative to implement effective conservation strategies, including sustainable harvesting practices, habitat restoration, and in-situ and ex-situ conservation efforts, to mitigate these threats and ensure the long-term survival of this valuable plant (Singh & Meena, 2023).

**Objectives**

This article aims to provide a comprehensive review of the conservation and ethnobotanical properties of *Acorus calamus*. The objectives are to:

1. Examine the plant's botanical characteristics and distribution.

2. Assess its conservation status and the challenges it faces.

3. Review its traditional uses and pharmacological properties.

4. Discuss sustainable management practices and identify research gaps for future studies.

**2. Botanical Description and Habitat**

**Taxonomy and Morphology**

*Acorus calamus* is a member of the family Acoraceae. The plant's taxonomy is as follows:

-Kingdom: Plantae

Division: Magnoliophyta

Class: Liliopsida

Order: Acorales

Family: Acoraceae

-Genus: Acorus

Species: *Acorus calamus*

Common names for the plant include sweet flag, calamus, and beewort. Morphologically, *Acorus calamus* is recognized by its aromatic rhizomes, which are thick, branched, and have a yellowish-brown outer layer with a white inner core. The leaves are long, sword-shaped, and slightly curved, releasing a distinct aroma when crushed. The flowers are small, greenish-yellow, and arranged in a cylindrical spike known as a spadix (Gupta & Nair, 2017). Evidence based on studies of morphology, essential oil chemistry, cytology, isozymes, and ethnobotany supports the existence of two species in North America; *A. calamus*, an introduced sterile triploid, and *A. americanus*, a native fertile diploid. *A. americanus* is not only morphologically distinct from triploid *A. calamus* but also from diploid and tetraploid A. calamus populations occurring in Asia (Thompson 2002).



Fig 1 : Habitat and Distribution of *Acorus calamus*

**Habitat and Distribution**

*Acorus calamus* thrives in wetland habitats, including marshes, swamps, and along riverbanks. It is native to a wide geographical range, including regions in Asia (India, China, Japan), Europe (Russia, Poland, Germany), and North America (Li et al., 2018) . The plant prefers moist, acidic soils and can tolerate partial shade, making it well-suited to wetland environments. Its natural distribution has been impacted by habitat loss and degradation, particularly in areas where wetlands are drained for agriculture or development (Patel & Bhandari, 2020). Sweet flag is widespread and abundant throughout its native and non-native range in the Old World. It is widespread and abundant in parts of North America, and occurs non-native over a wide area. However, there have been local extinctions on the eastern seaboard (The Board of Trustees of the Royal Botanic Gardens, Kew 2013).

**3. Conservation Status and Challenges**

**Current Conservation Status**

The conservation status of ***Acorus calamus*** varies significantly by region. Globally, the plant is not listed as endangered on the IUCN Red List;but it is listed in least concern LC in red list( Lansdown, R.V. 2014). However, local populations are experiencing considerable threats. In many areas, especially in countries like India and China where ***Acorus calamus*** is extensively utilized for its medicinal properties, the plant faces significant risks. Overharvesting of its rhizomes for traditional medicine and commercial use has led to population declines in the wild. The high demand for the plant's therapeutic compounds has exacerbated this issue, leading to unsustainable harvesting practices that threaten its long-term survival (Kumar & Kumar, 2019; Patel & Bhandari, 2020).

Habitat destruction further compounds the problem. Wetland areas, which are crucial for the plant's growth, are being drained and converted for agricultural and urban development. This loss of habitat not only reduces the plant's natural distribution but also disrupts the ecosystems it supports (Singh & Meena, 2023). Pollution from agricultural runoff and industrial activities can also adversely affect ***Acorus calamus***, contaminating the water and soil in which it grows, thus impacting its health and reproductive success (Ray & Ghosh, 2021).

In response to these challenges, there is an urgent need for the implementation of sustainable management practices. Effective strategies include establishing protected areas to conserve natural habitats, promoting cultivation in controlled environments to reduce pressure on wild populations, and developing guidelines for sustainable harvesting. These measures are essential to ensure that ***Acorus calamus***can continue to thrive both ecologically and economically (Choudhary et al., 2022; Wang et al., 2019).

**Threats to Survival**

The primary threats to ***Acorus calamus*** include several interconnected factors that jeopardize its survival:

* **Habitat Destruction**: Wetland ecosystems, which are crucial for the growth and development of ***Acorus calamus***, are increasingly being lost due to drainage for agriculture, urbanization, and industrial expansion. The conversion of wetlands into agricultural fields or urban areas significantly reduces the plant's natural habitat, disrupting its ecological niche and diminishing its populations (Wang et al., 2019; Singh & Meena, 2023). This habitat destruction not only affects the plant directly but also impacts the biodiversity and ecological functions of the wetlands where it grows.
* **Pollution**: The contamination of wetlands from agricultural runoff, industrial discharge, and other pollutants poses a significant threat to ***Acorus calamus***. Pollutants such as pesticides and heavy metals can adversely affect the plant's growth, reproductive success, and overall health. These pollutants can degrade soil and water quality, further compromising the plant’s habitat and reducing its ability to thrive (Singh et al., 2020; Patel & Bhandari, 2020).
* **Climate Change**: Changes in climate patterns, including shifts in temperature and precipitation, are altering wetland ecosystems in which ***Acorus calamus*** is found. Increased temperatures and altered rainfall patterns can affect the water levels and soil conditions of wetlands, leading to unfavorable growing conditions for the plant. Additionally, climate change can exacerbate other threats such as habitat loss and pollution, making it a compound stressor for ***Acorus calamus*** (Wang et al., 2019; Gupta & Nair, 2017).
* **Overharvesting**: The high demand for ***Acorus calamus*** in traditional medicine, perfumery, and the herbal industry has led to overharvesting of its rhizomes. This excessive extraction reduces wild populations and disrupts the plant’s ability to regenerate naturally. Overharvesting not only threatens the plant's survival but also impacts the ecological balance of the wetland habitats where it is found (Sharma et al., 2021; Choudhary et al., 2022).

**Conservation Efforts and Strategies**

To mitigate these threats, several conservation strategies are being implemented:

* **In-situ Conservation**: Protecting and managing the natural habitats where ***Acorus calamus*** grows is essential for maintaining existing populations in the wild. Efforts include establishing protected areas, enforcing regulations to prevent habitat destruction, and promoting habitat management practices that support the plant’s growth and reproduction (Kumar & Kumar, 2019; Singh & Meena, 2023).
* **Ex-situ Conservation**: Cultivating ***Acorus calamu*s** in botanical gardens, research centers, and controlled environments helps preserve genetic diversity and provides a backup for wild populations. These ex-situ conservation efforts allow for the study and propagation of the plant, ensuring its survival and potential reintroduction into the wild (Choudhary et al., 2022; Li et al., 2018).
* **Habitat Restoration**: Restoring degraded wetlands to create suitable conditions for ***Acorus calamus*** growth is a critical conservation strategy. Restoration projects involve rehabilitating wetland areas that have been damaged by human activities, improving water quality, and re-establishing native plant communities to support the plant’s ecological needs (Singh & Meena, 2023; Ray & Ghosh, 2021).
* **Community-Based Conservation Programs**: Engaging local communities in conservation efforts and promoting sustainable use practices are vital for the long-term protection of ***Acorus calamus***. Community-based programs aim to raise awareness about the plant’s ecological and medicinal value, encourage sustainable harvesting practices, and involve local stakeholders in habitat management and restoration activities (Choudhary et al., 2022; Patel & Bhandari, 2020).

Sustainable harvesting of ***Acorus calamus*** is essential for ensuring the long-term conservation of the species and maintaining its ecological balance. Effective guidelines for sustainable collection include:

* **Rotational Harvesting**: Implementing rotational harvesting involves periodically allowing specific areas to rest and recover between harvests. This practice helps prevent overexploitation and supports the regeneration of plant populations by giving them time to replenish their rhizomes and seeds. Rotational harvesting ensures that the entire habitat is not depleted and maintains the plant's ecological role in its environment (Patel & Bhandari, 2020; Choudhary et al., 2022).
* **Restricting Harvest Seasons**: Limiting harvesting to specific seasons or times of the year aligns with the plant's growth and reproductive cycles. For ***Acorus calamus***, this means harvesting during periods when the plant's rhizomes are mature and storing energy for the next growing season. By avoiding collection during critical growth phases, the plant’s ability to regenerate and sustain its populations is preserved (Li et al., 2018; Singh & Meena, 2023).
* **Promoting Cultivation in Controlled Environments**: Cultivating ***Acorus calamus*** in botanical gardens, research farms, or agroforestry systems reduces the pressure on wild populations. Controlled environments allow for the study of optimal growing conditions and the development of cultivation techniques that can be applied to support conservation efforts. Additionally, this practice helps meet the demand for the plant’s medicinal and commercial uses without depleting natural habitats (Patel & Bhandari, 2020; Gupta & Nair, 2017).
* **Implementing Best Practices for Harvesting**: Adopting best practices for harvesting, such as using non-destructive methods and minimizing soil disturbance, is crucial for reducing the impact on the environment. Techniques like hand digging or using specialized tools can help ensure that the plant's rhizomes are harvested with minimal damage to the surrounding habitat (Ray & Ghosh, 2021; Choudhary et al., 2022).
* **Monitoring and Regulation**: Regular monitoring of ***Acorus calamus*** populations and enforcing regulations to prevent illegal or unsustainable harvesting practices are necessary for conservation. Collaborative efforts with local communities and stakeholders can help in the development and enforcement of these regulations, ensuring that harvesting remains sustainable and does not lead to population declines (Singh & Meena, 2023; Sharma et al., 2021).

By adhering to these guidelines, the sustainable management of ***Acorus calamus*** can be achieved, balancing the plant’s ecological importance with its economic and medicinal value.

**4. Ethnobotanical Uses**

**Traditional Medicinal Uses**

*Acorus calamus* has a rich history of use in traditional medicine across various cultures. Its medicinal applications are diverse and include:

* **Digestive Health:** The rhizomes of *Acorus calamus* are traditionally used to address gastrointestinal issues such as indigestion, flatulence, and stomach cramps. These effects are attributed to its carminative and antispasmodic properties, which help soothe the digestive tract and relieve discomfort (Sharma et al., 2021; Patel & Bhandari, 2020).
* **Respiratory Ailments:** The plant's rhizomes are utilized to alleviate symptoms of respiratory conditions, including coughs, colds, and bronchitis. Its expectorant properties aid in clearing mucus from the respiratory tract, providing relief from congestion and associated discomfort (Singh et al., 2020; Li et al., 2018).
* **Cognitive Enhancement:** In traditional medicine systems, particularly Ayurveda, *Acorus calamus* is believed to support cognitive function and memory enhancement. Its use as a notropic herb is well-documented, with historical references highlighting its role in improving mental clarity and focus (Sharma et al., 2021; Ray & Ghosh, 2021).
* **Antimicrobial and Anti-inflammatory Properties:** *Acorus calamus* exhibits notable antimicrobial and anti-inflammatory effects, which are used to treat infections and manage inflammatory conditions. The plant's bioactive compounds, including alpha-asarone and beta-asarone, contribute to these therapeutic properties (Gupta & Nair, 2017; Choudhary et al., 2022).
* **Sedative and Anxiolytic Effects:** The rhizomes of *Acorus calamus* are traditionally employed to manage stress, anxiety, and insomnia. Its mild sedative properties help promote relaxation and improve sleep quality, making it a valuable herb for managing mental and emotional well-being (Sharma et al., 2021; Singh & Meena, 2023).

**Cultural and Ritual Significance**

In addition to its medicinal applications, ***Acorus calamus*** holds substantial cultural and spiritual importance across various traditions. It is commonly utilized in rituals and ceremonies aimed at purification and protection. For instance, in Hindu rituals, ***Acorus calamus*** is used in the form of incense to cleanse spaces and invite positive energies (Li et al., 2018). In some Native American traditions, the plant is used in smudging ceremonies to purify individuals and environments. Its aromatic properties make it a popular choice for incense and potpourri, where its scent is believed to have calming and uplifting effects (Li et al., 2018).

**Other Ethnobotanical Applications**

* **Culinary Uses**: ***Acorus calamus*** is also valued for its culinary applications in various cultures. The young shoots and rhizomes are used as a flavoring agent in foods and beverages, adding a distinct aroma and taste. In some Asian cuisines, ***Acorus calamus*** rhizomes are employed to flavor dishes and traditional beverages, reflecting its longstanding role in culinary practices (Patel & Bhandari, 2020).
* **Insect Repellent**: Traditionally, ***Acorus calamus*** has been used as a natural insect repellent. The plant’s essential oils are known to repel mosquitoes and other insects, making it a practical choice for natural pest control in some regions (Sharma et al., 2021). This application highlights its utility beyond medicinal uses, showcasing its versatility in traditional pest management practices.
* **Perfumery and Aromatherapy**: The plant’s fragrant rhizomes are highly valued in the fields of perfumery and aromatherapy. The essential oils extracted from ***Acorus calamus*** are used to create perfumes and aromatherapy products due to their pleasant aroma and therapeutic properties. The aromatic compounds are believed to have calming effects, contributing to their popularity in wellness and cosmetic products (Singh et al., 2020).

These diverse applications of ***Acorus calamus*** underscore its significance across various domains, from cultural rituals to practical uses in everyday life.

### 5 Phytochemical Composition and Pharmacological Properties

**Phytochemical Profile**

**Acorus calamus** is rich in a variety of bioactive compounds that contribute to its medicinal properties:

* **Alpha-asarone and Beta-asarone**: These are the primary components responsible for the majority of the plant's therapeutic effects. Alpha-asarone, in particular, has been shown to possess potent antispasmodic and neuroprotective properties. Beta-asarone has demonstrated anti-inflammatory and analgesic effects, making both compounds critical in the plant's pharmacological profile (Sharma et al., 2021; Ray & Ghosh, 2021).
* **Eugenol**: This compound is well-regarded for its antimicrobial and anti-inflammatory properties. Eugenol, a phenolic compound found in ***Acorus calamus***, has been effective against a range of bacterial and fungal pathogens and is used for its analgesic properties (Gupta & Nair, 2017; Singh & Meena, 2023).
* **Other Compounds**: The plant also contains flavonoids, tannins, and glycosides. These compounds contribute to its antioxidant, anti-inflammatory, and antimicrobial effects. Flavonoids have been noted for their potential in reducing oxidative stress, while tannins and glycosides play roles in modulating inflammation and supporting overall health (Sharma et al., 2021; Patel & Bhandari, 2020).

**Pharmacological Studies**

Numerous studies have substantiated the traditional uses of ***Acorus calamus***and explored its pharmacological potentials:

* **Antimicrobial and Anti-inflammatory Properties**: Scientific research has confirmed the plant's effectiveness in combating microbial infections and reducing inflammation. These properties are largely attributed to the presence of alpha-asarone and eugenol, which have shown significant activity against various pathogens and inflammatory conditions (Gupta & Nair, 2017; Sharma et al., 2021).
* **Cognitive Enhancement**: Recent studies have investigated the potential of ***Acorus calamus*** in enhancing cognitive function. Research has shown that compounds like alpha-asarone may improve memory and cognitive performance, making the plant a subject of interest for addressing neurodegenerative diseases (Singh & Meena, 2023; Sharma et al., 2021).
* **Sedative Effects**: The plant's sedative properties have been validated through pharmacological research, highlighting its use in managing anxiety and sleep disorders. Alpha-asarone, in particular, has been noted for its calming effects, which can be beneficial in therapeutic applications for stress and insomnia (Sharma et al., 2021; Singh et al., 2020).

Recent advances in phytochemical research have focused on isolating and characterizing these bioactive compounds to explore their full potential for pharmaceutical development. This ongoing research aims to translate traditional uses into modern therapeutic applications, enhancing the value of ***Acorus calamus*** in contemporary medicine (Sharma et al., 2021; Ray & Ghosh, 2021).

**6. Sustainable Management and Future Directions**

To ensure the long-term sustainability of ***Acorus calamus***, adopting cultivation practices that balance environmental stewardship with productive efficiency is crucial. Key strategies include:

* **Organic Farming**: Implementing organic farming techniques allows for the cultivation of ***Acorus calamus*** without the use of synthetic chemicals or pesticides. This approach not only promotes soil health and reduces environmental contamination but also aligns with traditional practices that often emphasize natural growth methods (Patel & Bhandari, 2020). Organic farming can enhance the plant's resilience and support the maintenance of ecological balance within its cultivation area.
* **Agroforestry Systems**: Integrating ***Acorus calamus*** cultivation into agroforestry systems provides multiple benefits. By combining the plant with other crops or trees, these systems can enhance biodiversity, improve soil fertility, and reduce the risk of pest infestations. Agroforestry practices help create a more resilient ecosystem that supports various plant and animal species while optimizing land use (Choudhary et al., 2022). This method also contributes to sustainable land management and can provide economic benefits to local farmers.
* **Genetic Improvement**: Investing in research to develop genetically improved varieties of ***Acorus calamus*** can significantly enhance cultivation outcomes. Efforts should focus on breeding plants with faster growth rates, increased disease resistance, and higher concentrations of bioactive compounds. Genetic improvement can lead to more robust and productive plants, contributing to greater yields and improved quality of harvested rhizomes (Singh & Meena, 2023). Such advancements not only support the commercial viability of cultivation but also help maintain genetic diversity and resilience.

These sustainable cultivation practices are essential for maintaining the ecological and economic viability of ***Acorus calamus*** cultivation, ensuring that this valuable plant can continue to provide its benefits while preserving environmental integrity.

**Research Gaps and Future Studies**

While progress has been made in understanding the ethnobotanical significance and conservation status of ***Acorus calamus***, several critical research gaps warrant further investigation to ensure the species' sustainability and optimize its benefits:

* **Conservation Genetics**: There is a need for comprehensive studies on the genetic diversity of wild ***Acorus calamus*** populations. Assessing genetic variation and structure is crucial for informing conservation strategies, such as identifying genetic bottlenecks, understanding the effects of overharvesting, and maintaining genetic diversity to ensure the species' long-term viability (Kumar & Kumar, 2019; Gupta & Nair, 2017). These studies can help develop targeted conservation measures that address genetic erosion and enhance population resilience.
* **Ecological Impact of Harvesting**: Research is required to understand the ecological consequences of harvesting ***Acorus calamus*** on wetland ecosystems. Investigating how harvesting practices affect soil stability, aquatic habitats, and overall ecosystem health can help develop sustainable harvesting guidelines. This research should focus on the direct and indirect impacts of different harvesting methods, including soil disruption and changes in plant community dynamics (Wang et al., 2019; Li et al., 2018). Understanding these impacts will guide the creation of best practices that minimize environmental harm and support ecosystem function.
* **Pharmacological Research**: Further pharmacological research is necessary to isolate, characterize, and understand the bioactive compounds in ***Acorus calamus***. Studies should focus on identifying new bioactive components and elucidating their mechanisms of action at the molecular level. This includes evaluating how these compounds interact with biological targets such as enzymes and receptors, which is essential for developing new therapeutic applications and improving existing medicinal uses (Sharma et al., 2021; Ray & Ghosh, 2021). Advanced techniques such as chromatography and mass spectrometry can facilitate these investigations.
* **Climate Change Adaptation**: Research on the potential impacts of climate change on ***Acorus calamus*** is crucial for developing adaptive management strategies. Studies should explore how shifts in temperature, precipitation patterns, and water availability affect the plant's growth, reproduction, and distribution. Understanding the species' physiological and phenological responses to climate change will help predict future challenges and inform habitat management and restoration efforts (Singh & Meena, 2023; Wang et al., 2019). This research can aid in developing strategies to enhance the plant's resilience to changing environmental conditions.

Addressing these research gaps will contribute to the effective conservation and sustainable management of ***Acorus calamus***, ensuring its continued availability and ecological benefits for future generations.

**Conclusion**

***Acorus calamus***, commonly known as sweet flag, is a plant of immense ethnobotanical and ecological significance, widely utilized in traditional medicine, perfumery, and as a natural insect repellent. Its rhizomes are especially valued for their therapeutic properties, treating various ailments such as digestive issues, fever, and anxiety, and are integral to cultural and spiritual practices in many regions. Ecologically, *Acorus calamus* plays a vital role in wetland ecosystems by stabilizing soil, supporting aquatic life, and purifying water through phytoremediation. However, the plant is increasingly threatened by overexploitation, habitat loss due to wetland degradation and urbanization, and the impacts of climate change, all of which contribute to its declining populations in the wild. To protect this species, it is crucial to implement effective conservation strategies, including in-situ and ex-situ conservation efforts, sustainable harvesting guidelines, and continued research into its diverse applications and cultivation methods. Ensuring the sustainable management and protection of *Acorus calamus* is vital to preserving its ecological functions and ethnobotanical value, safeguarding its availability and benefits for future generation.

**References**

1. **Bhagwat RV, Boralkar DB, Chavhan RD.** (2018) Remediation capabilities of pilot-scale wetlands planted with *Typha aungstifolia* and *Acorus calamus* to treat landfill leachate. Journal of Ecology and Environment 42: 23.
2. **Chen G, Li Q, Bai M, Chen Y.** (2019) Nitrogen metabolism in *Acorus calamus* L. leaves induced changes in response to microcystin-LR at environmentally relevant concentrations. Bulletin of Environmental Contamination and Toxicology 103: 280–285.
3. **Choudhary, P., Singh, R., & Meena, M.** (2022). Sustainable cultivation practices for *Acorus calamus*: A review. \*Journal of Plant Sciences\*, 12(2), 85-102.
4. **Choudhary, S., et al.** (2022). "Sustainable Harvesting and Cultivation Practices of *Acorus calamus*: A Step Towards Conservation." *Journal of Ethnobiology and Ethnomedicine, 18*(1), 22-34.
5. **Gupta, A., & Nair, S.** (2017). "Phytochemical Screening and Antimicrobial Activity *of Acorus calamus* Rhizomes." *Indian Journal of Traditional Knowledge, 16*(4), 527-534.
6. **Gupta, R., & Nair, M**. (2017). Phytochemical and pharmacological properties of *Acorus calamus*: A comprehensive review. Journal of Herbal Medicine\*, 5(1), 35-49.
7. **IUCN. 2014.** The IUCN Red List of Threatened Species. Version 2014.1. Available at: www.iucnredlist.org. (Accessed: 12 June 2014).
8. **Kumar, A., & Kumar, R.** (2019). Conservation genetics of *Acorus calamus*: Implications for biodiversity preservation. \*Genetic Resources and Crop Evolution\*, 66(4), 985-995.
9. **Kumar, A., & Kumar, S.** (2019). "Conservation Strategies for Wetland Plants: A Case Study of *Acorus calamus*." *Environmental Science and Conservation Journal, 10*(2), 105-112.
10. Lansdown, R.V. 2014. *Acorus calamus*. The IUCN Red List of Threatened Species 2014: e.T168639A43116307. <http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T168639A43116307.en>.
11. **Li, X., et al**. (2018). "Traditional Uses, Phytochemistry, and Pharmacology of *Acorus calamus* in Asia: A Review." *Journal of Herbal Medicine, 14*, 50-65.
12. **Li, Z., Wang, Y., & Zhang, X.** (2018). Ethnobotanical and ecological significance of *Acorus calamus*. \*Botanical Review\*, 84(3), 45-60.
13. **Patel, M., & Bhandari, S.** (2020). "Conservation and Sustainable Use of Medicinal Plants: The Case of *Acorus calamus*." *Journal of Environmental Management, 261*, 110203.
14. **Patel, M., & Bhandari, S. (2020).** "Conservation and Sustainable Use of Medicinal
15. **Patel, S., & Bhandari, A.** (2020). The ethnobotanical significance of *Acorus calamus* in traditional medicine. \*Journal of Ethnopharmacology\*, 15(5), 105-115.
16. **Ray, S., & Ghosh, T.** (2021). "Ethnobotanical Significance and Phytochemical Analysis of Acorus calamus in Indian Traditional Medicine." *Journal of Applied Research on Medicinal and Aromatic Plants, 25*, 100332.
17. **Sharma, N., et al.** (2021). "Ethnopharmacological Properties of *Acorus calamus*: A Comprehensive Review." *Journal of Ethnopharmacology, 260*, 113021.
18. **Sharma, P., Singh, V., & Meena, R.** (2021). Therapeutic potential of *Acorus calamus*: A phytochemical and pharmacological perspective. \*Phytomedicine Research\*, 28(7), 335-347.
19. **Shooto N.D.** (2020) Removal of toxic hexavalent chromium (Cr(VI)) and divalent lead (Pb(II)) ions from aqueous solution by modified rhizomes of *Acorus calamus*. Surfaces and Interfaces 20: 100624.
20. **Singh, M., & Meena, K.** (2023). Impact of climate change on wetland plants: A case study of *Acorus calamus.* \*Environmental Botany\*, 19(1), 75-88.
21. **Singh, P., & Meena, V.** (2023). "Biological Conservation of Wetland Ecosystems: Focusing on *Acorus calamus* Populations." *Wetlands Ecology and Management, 31*(2), 229-243.
22. **Singh, R., et al. (2020).** "Phytochemistry and Ethnobotanical Review of *Acorus calamus*." *Journal of Medicinal Plants Studies, 8*(3), 15-24.
23. **Singh, R., et al. (2020).** "Phytochemistry and Ethnobotanical Review of *Acorus calamus*." *Journal of Medicinal Plants Studies, 8*(3), 15-24.*: Acorus calamus* as a case study. \*Wetlands Ecology and Management\*, 27(3), 415-429.
24. The Board of Trustees of the Royal Botanic Gardens, Kew. 2010. World Checklist of Selected Plant Families. Available at: <http://www.kew.org/wcsp>.
25. **Thompson, S.A. 2002**. Acoraceae. In Flora of North America North of Mexico. Vol. 22. Oxford University Press, New York and Oxford.
26. **Wang, J., et al.** (2019). "Impact of Climate Change on the Distribution of Wetland Plants: A Study on *Acorus calamus*." *Global Ecology and Conservation, 20*, e00756.
27. **Wang, J., et al. (2019).** "Impact of Climate Change on the Distribution of Wetland Plants: A Study on *Acorus calamus*." *Global Ecology and Conservation*, 20, e00756.
28. **Wang, J., Li, Q., & Chen, S.** (2019). Habitat restoration and conservation of wetland plant*s*.
29. **Zhang S, Zhang S, Li G.** (2016) *Acorus calamus* root extracts to control harmful cyanobacteria blooms. Ecological Engineering 94: 95–101.