

Year - 2026

Vol. 13, No. 1

(ISSN 2395 - 468X)

Issue: January 2026

वनसंज्ञान

Van Sangyan

A monthly open access e-magazine



Indexed in:



COSMOS
Foundation
(Germany)



International
Inst. of Org. Res.
(Australia)



IJIF



ICFRE-Tropical Forest Research Institute
(Indian Council of Forestry Research and Education)

Ministry of Environment, Forests and Climate Change (MoEFCC)
PO RFRC, Mandla Road, Jabalpur – 482021, India

Van Sangyan

Editorial Board

Patron:	Director
Co Patron:	Group Coordinator (Research)
Chief Editor:	Dr. Naseer Mohammad
Editor & Coordinator:	Shri M. Rajkumar
Assistant Editor:	Dr. Rajesh Kumar Mishra

Note to Authors:

We welcome the readers of Van Sangyan to write to us about their views and issues in forestry. Those who wish to share their knowledge and experiences can send them:

by e-mail to vansangyan_tfri@icfre.org

or, through post to

The Editor, Van Sangyan,
ICFRE-Tropical Forest Research Institute,
PO-RFRC, Mandla Road,
Jabalpur (M.P.) - 482021.

The articles can be in English, Hindi, Marathi, Chhattisgarhi and Oriya, and should contain the writers name, designation and full postal address, including e-mail id and contact number. TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve



From the Editor's desk

Firm to forest: Where profit meets the planet captures a defining transition in contemporary economic thought—the recognition that long-term profitability and planetary stewardship are no longer competing objectives but mutually reinforcing imperatives. In an era marked by climate volatility, biodiversity loss, and tightening regulatory and investor scrutiny, firms that internalize environmental responsibility are discovering strategic advantage rather than sacrifice. From regenerative supply chains and nature-positive accounting to carbon markets and ecosystem services valuation, the integration of forests into corporate strategy is reshaping how value is created and measured. Forests are no longer viewed merely as externalities or offsets; they are emerging as productive assets that stabilize climate risk, secure raw materials, enhance brand trust, and unlock green finance. This shift demands rigorous governance, credible science, and transparency to avoid greenwashing, yet the direction is unmistakable: enterprises that align capital with conservation are better positioned to endure shocks, attract investment, and innovate responsibly. The journey from firm to forest is not philanthropy—it is a recalibration of capitalism itself, where profit is sustained precisely because the planet is protected.

In line with the above this issue of Van Sangyan contains an article on Firm to forest: Where profit meets the planet. There are also useful articles viz. Synthetic seeds for the conservation of forest trees, Biochars from invasive biomass: Pine needles and Lantana camara for soil health, Pongamia pinnata (L.) Pierre: A tree of many uses, Bioprospecting: Creating value for biodiversity, Agroforestry and biodiversity conservation: Nurturing life above and below the ground, शहरी-वानिकी से पर्यावरणीय संतुलन: चुनौतियाँ एवं संभावनाएँ (विश्लेषणात्मक अध्ययन) , and सर्दी-खांसी से कैंसर तक: कुलंजन के चमत्कारी फायदे.

Looking forward to meet you allthrough forthcoming issues

Dr. Naseer Mohammad

Chief Editor



Disclaimer – Van Sangyan

Statement of Responsibility

Neither *Van Sangyan* (VS) nor its editors, publishers, owners or anyone else involved in creating, producing or delivering *Van Sangyan* (VS) or the materials contained therein, assumes any liability or responsibility for the accuracy, completeness, or usefulness of any information provided in *Van Sangyan* (VS), nor shall they be liable for any direct, indirect, incidental, special, consequential or punitive damages arising out of the use of *Van Sangyan* (VS) or its contents. While the advice and information in this e-magazine are believed to be true and accurate on the date of its publication, neither the editors, publisher, owners nor the authors can accept any legal responsibility for any errors or omissions that may be made or for the results obtained from the use of such material. The editors, publisher or owners, make no warranty, express or implied, with respect to the material contained herein.

Opinions, discussions, views and recommendations are solely those of the authors and not of *Van Sangyan* (VS) or its publishers. *Van Sangyan* and its editors, publishers or owners make no representations or warranties with respect to the information offered or provided within or through the *Van Sangyan*. *Van Sangyan* and its publishers will not be liable for any direct, indirect, consequential, special, exemplary, or other damages arising there from.

Van Sangyan (VS) reserves the right, at its sole discretion, to change the terms and conditions from time to time and your access of *Van Sangyan* (VS) or its website will be deemed to be your acceptance of an agreement to any changed terms and conditions.



Contents		Page
1.	Firm to forest: Where profit meets the planet - Paritosh kumar, Rakesh Choudhary, Vikash Kumar and Ajoy Das	1
2.	Synthetic seeds for the conservation of forest trees - Vishwajith Podila, Shalini Mudalkar and Ravi Kiran Potluri	5
3.	Biochars from invasive biomass: Pine needles and Lantana camara for soil health - Ibajanai Kurbah, Sanjeev Kumar and Rupam Nehta	12
4.	<i>Pongamia pinnata</i> (L.) Pierre: A tree of many uses - Soboro Komal, N. Ramakrishna, Yerkala Kumar, Pottepaka Shraavan, Gaddam Sudharshan Reddy, Modala Rakesh	17
5.	Stop pruning of wood-yielding trees (Teak and Sandalwood)- Grow morewood and use more wood - R. Sundararaj and Ramkumar V R	25
6.	Bioprospecting: Creating value for biodiversity - Surabhi Sharma, Kavita Kumari Thakur, Bhupender Dutt and Rohit Sharma	31
7.	Agroforestry and biodiversity conservation: Nurturing life above and below the ground - Babita Kumari and Pooja Sharma	41
8.	शहरी-वानिकी से पर्यावरणीय संतुलन: चुनौतियाँ एवं संभावनाएँ (विश्लेषणात्मक अध्ययन) - अनिमेष शुक्ला, पूनम खेस, सिंधु खाखा एवं पार्वती ताम्रकार	48
9.	उत्तर प्रदेश के जनपद बुलंदशहर में एडनसोनिया डिजिटटा (<i>Adansonia digitata</i> Linn) के पेड़ पर एंथेसिस के समय पर सर्वेक्षण - यशवंत राय	56
10.	सर्दी-खांसी से कैसर तक: कुलंजन के चमत्कारी फायदे - अंकुर ज्योति शेकीया	65



Firm to forest: Where profit meets the planet

Paritosh kumar¹, Rakesh Choudhary², Vikash Kumar³ and Ajoy Das¹

¹Joint Directorate of Extension Education

ICAR-Indian Veterinary Research Institute, Izatnagar

²Department of Dairy Trade and Dairy Business Management

College of Dairy and Food Technology, Bassi, Jaipur

³Dairy Extension Division, ICAR- National Dairy Research Institute, Karnal

Introduction

In Anera of fast-paced industrial revolution and rising environmental concerns, the tale of India's green cover and forests offers both a warning and an opportunity. As urbanisation accelerates, cities expand and industries thrive, India's green cover continues to shrink rapidly during 20th century but in 21st century a ray of hope is seen as multiple stakeholders are coming together in order to protect and restore what has been lost. India is one of the few nations globally that has recorded a steady rise in forest cover over the past two decades. This positive change has been possible because India has consistently given importance to protecting its forests. Both the Central and State governments have worked together through strong laws and dedicated programmes. Efforts like The Indian Forest Act, 1927, Wildlife (Protection) Act, 1972, National Forest Policy, 1988, Van Sanrakshan Evam Samvardhan Adhiniyam, 1980, Central and State sponsored Schemes like Green India Mission (GIM), CAMPA, MGNREGA, National Afforestation Programme (NAP), Policy for enhancement of Urban Greens, National Agro-forestry Policy, Sub-Mission on Agro-forestry (SMAF), etc. have helped communities plant more trees, restore degraded land, and care for forests (FSI, 2023). Apart from these government-led based movements, a new movement is taking root. Across India, companies are turning their profits into purpose through Corporate Social Responsibility (CSR) initiatives that are restoring forests, conserving biodiversity,

and empowering communities adding a powerful dimension to this success.

Corporate Social Responsibility (CSR)

According to McWilliams and Siegel (2001), Corporate Social Responsibility (CSR) is "Situations where the firm goes beyond compliance and engages in actions that appear to further some social good, beyond the interests of the firm and that which is required by law." In India, the idea of corporate social responsibility goes beyond goodwill, it's built into the law. Section 135 of the Companies Act of 2013 and the Companies (Corporate Social Responsibility) Rules of 2014 establish the legal foundation for corporate social responsibility (CSR) initiatives by the government. With effect from April 1, 2014, organizations that meet the requirements outlined in Subsection 1 of Section 135 are required to comply with the provisions pertaining to Corporate Social Responsibility by virtue of the "CSR Rules" and other related announcements. This legal provision has opened the door for India's corporate sector to become a major ally in forest conservation and restoration.

Activities under Corporate Social Responsibility (CSR)

Schedule VII outlines the types of activities companies can support through their CSR initiatives. These include efforts to reduce hunger and poverty, promote education, advance gender equality, improve child and maternal health, fight major diseases, protect the environment, develop vocational skills, support social business projects, and contribute to government relief and welfare funds. It



also allows for any other activities notified by the government.

CSR scenario in India

In the financial year 2023-24, about 27,188 companies in 40 States and Union Territories across 14 development sectors carried 59,633 projects and spent ₹34908.75 crores. Maharashtra, Gujarat and Karnataka are the top 3 states with spending of about ₹6065.95, ₹2707.54 and ₹2254.88 crores, respectively. HDFC Bank Limited leads CSR spending with ₹921.96 crore, followed by Reliance Industries Limited at ₹899.07 crore and Tata Consultancy Services at ₹812.65 crore. ONGC (₹612.42 crore) and Tata Steel (₹572.74 crore) also made good contributions, which highlights strong corporate commitment to social welfare. Development Sectors like Education, Differently Abled, livelihood with ₹16,287.78 crores, Health, Eradicating Hunger, Poverty and Malnutrition, Safe Drinking water, Sanitation with ₹9087.41 crores and Environment, Animal Welfare, Conservation of Resources with ₹3456.05 crores, emerged out as top 3 in the financial year 2023-24 (Ministry of Corporate Affairs, 2025).

CSR in action: Case studies

ITC's biodiversity programme



ITC Limited has shown how corporate initiatives can turn barren lands into thriving ecosystems. Through its

biodiversity projects, ITC provides quality saplings, technical support, and buyback assurances to farmers. This not only increases rural incomes but also adds thousands of hectares to India's green cover. During the last year, ITC's community projects successfully conserved more than 1.76 lakh acres of biodiversity area. This recent growth has brought the total area conserved through their efforts to a cumulative of over 6.47 lakh acres.

ITC's Mission SunehraKal (MSK) is piloting Miyawaki forest which is a quick, two-year method for creating dense ecosystems as a part of the global effort to increase green cover. Recognizing the technique's high price tag, MSK is innovating to develop affordable ways to implement it, including leveraging government schemes. Their efforts in Water Stewardship and Biodiversity Conservation are significantly strengthened by key partnerships with state governments across India (Andhra Pradesh, Maharashtra, Rajasthan, and Karnataka) and with NABARD (ITC Limited, 2025).

ONGC's green driv

The Oil and Natural Gas Corporation (ONGC) has invested heavily in afforestation and biodiversity conservation projects. From supporting large-scale plantation drives in degraded areas to protecting mangroves and wildlife habitats, ONGC's initiatives demonstrate how heavy industries can give back to nature. The ONGC-Mahesana project is a Corporate Social Responsibility (CSR) initiative by Oil and Natural Gas Corporation Limited (ONGC), executed in partnership with the CATCH Foundation, to restore degraded public land in Santhal, Mehsana, Gujarat. The core of the project is the creation of a dense, native Miyawaki dense forest by planting 5,000 trees using the rapid afforestation method. Initiated in February 2024, the foundation's team is



responsible for implementing the Catch Forest Conservation System and ensuring the survival and maintenance of the forest over a three-year period. This initiative aims to transform the barren landscape into a thriving ecosystem, providing environmental benefits such as improved water conservation and groundwater recharge, while also creating employment opportunities for the local community (Catch Foundation, n.d.).

Tata Steel foundation's biodiversity efforts

In Jharkhand and Odisha, Tata Steel Foundation is restoring local ecosystems through biodiversity conservation programs. Their projects promote native tree species, environmental education, and community stewardship, linking conservation goals with human well-being. Tata Steel is actively improving city landscapes by focusing on urban forestry and biodiversity. A prime example is the Kailash Top Biodiversity Park in Jamshedpur, where they took a desolate 30-acre ash mound and revitalized it into a green haven with 25,000 plants. Furthermore, just last year (2024), the company launched an 11-acre nature trail in Sidhgora, Jharkhand. This project successfully replaced barren ground with a rich, native ecosystem, introducing 14,000 saplings and 5,000 shrubs representing over 60 species (UNGC, 2025).

SBI foundation's save the earth initiative:

The goal of this project is to use extensive afforestation to fight climate change and biodiversity loss. The project intends to improve carbon sequestration, rehabilitate damaged landscapes, and increase long-term environmental resilience by planting 10,000 trees. By 2027, the project is anticipated to offset about 10,000 tons of carbon emissions yearly; supporting the SBI Foundation's goal of promoting ecological balance and aligning with India's commitment to sustainable

development. The initiative has generated significant environmental and social impact. By reclaiming 50–70 hectares of degraded land and planting endemic tree species, it has contributed to biodiversity conservation and ecological restoration. The project involves the plantation of indigenous, water-retaining, and medicinal species such as Amaltas, Aonla, Aritha, Baans, Baheda, Bilb, Churel, Desi Babool, Hawan, Imli, Jamun, Karanj, Karonda, Katkarnaj, Kher, Khirni, Kikar, Mahuwa, Neem, Shikakai, along with other agri-horti species. It also aims to harness Traditional Ecological Knowledge, an evolving body of knowledge acquired by indigenous and local communities through generations of direct interaction with their environment, to enhance the sustainable growth and management of natural resources. Designed to be inclusive and community based, the project emphasizes collaboration with rural populations. The equitable and sustainable harvesting of Non-Timber Forest Products (NTFPs) and Minor Forest Produce (MFP) is expected to directly benefit 500 tribal households who depend on forest-based livelihoods (UNGC, 2025).

Beyond trees: Empowering forest communities

Corporate Social Responsibility in forestry is not just about planting trees; it's about planting opportunities. Many corporate programs are designed to strengthen forest-based livelihoods, particularly for tribal and rural populations. Initiatives such as promoting non-timber forest products (NTFPs), developing local nurseries, and training communities in eco-tourism or sustainable harvesting have created long-term benefits for both people and the planet. In India, Corporate Social Responsibility collaborations with local forest departments and NGOs are helping communities plant native fodder and fruit species, combining ecological



restoration with livelihood enhancement of these communities.

Conclusion

The rise of forestry based Corporate Social Responsibility activities marks a quiet revolution in India's development story. From reforestation and watershed management to promoting agroforestry and sustainable livelihoods, companies are now playing a visible role in rebuilding green ecosystems thus, proving that business and biodiversity can indeed grow together in a sustainable manner. Companies are realizing that sustainability is not charity's strategy. By restoring forests, protecting biodiversity, and engaging local communities, businesses are not only offsetting their ecological footprints but also building credibility, resilience, and trust. In this new era of responsibility, profit and planet no longer stand apart, they grow together, like trees in a shared canopy.

References

- CATCH Foundation. (n.d.). *ONGC-Mahesana*. Retrieved on November 27, 2025, from <https://catchfoundation.in/projects/ongc-mahesana>
- Forest Survey of India. (2023). *India State of Forest Report 2023: Volume 1*. Ministry of Environment, Forest and Climate Change, Government of India
- ITC Limited. (2025). *ITC Sustainability Report 2025*. Retrieved from <https://itcportal.com/content/dam/itc-corporate/open-pdfs/sustainability-reports/itc-sustainability-report-2025.pdf> on November 26, 2025.
- McWilliams, A., & Siegel, D. (2001). Corporate social responsibility: A theory of the firm perspective. *Academy of Management Review*, 26(1), 117–127. <https://doi.org/10.5465/amr.2001.4011987>

Ministry of Corporate Affairs. (n.d.). *Corporate Social Responsibility (CSR)*. Government of India. Retrieved on November 26, 2025 from

<https://www.csr.gov.in/content/csr/global/master/home/home.html>

UN Global Compact Network India. (2025). *Case studies of corporate-led initiatives on biodiversity conservation*. Retrieved on November 26, 2025 from <https://globalcompact.in/wp-content/uploads/2025/06/UNGCNI-Case-Studies-Business-and-Biodiversity-in-India.pdf>



Synthetic seeds for the conservation of forest trees

Vishwajith Podila, Shalini Mudalkar and Ravi Kiran Potluri

Department of Forest Biology and Tree Improvement

Forest College and Research Institute, Siddipet

Telangana502279

Email:vishwajithpodila@gmail.com

Introduction

The seed, often referred to as the zygotic seed, acts as the channel connecting consecutive plant generations throughout a substantial percentage of the plant kingdom. Seeds allow plants to transmit their genetic information to future

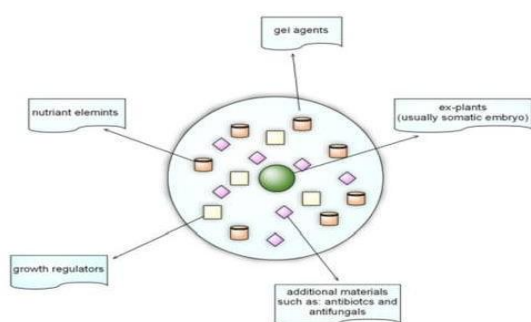


Fig.1: Synthetic seed structure

generations, making them ideal for functions such as reproduction, preservation, and distribution (Dhabhai Ravi et al., 2012). Artificial seeds show great potential for cost-effective mass production of plants, providing a viable alternative to conventional seeds (Roy, B et al., 2008). Although certain plants may be reproduced a sexually, traditional techniques are characterized by their sluggishness, high cost, and restricted ability to facilitate extensive plant cultivation. Synthetic seed technology has the potential to be a crucial solution for

creating artificial seeds, known as Syn-seeds. This technology offers an important alternative to current traditional methods for multiplying and preserving valuable crop varieties on a large scale (Potshangbam, 2016). Certain plants may be reproduced vegetatively, but, traditional techniques are both time-consuming and costly, and are limited in their ability to grow plants on a wider scale. The use of synthetic seed technology in the production of artificial seeds/synseeds can serve as a viable alternative to conventional techniques for the widespread multiplication and long-term preservation of valuable crop types (Gantait et al., 2015).

In vitro culture techniques are utilised to create plant micropropagules for synthetic seed formation using systems such as somatic embryogenesis, organogenesis, apical bud, protocorm, and protocorm-resembling bodies (PLBs) proliferation. The encapsulation procedure has been utilised to manufacture synthetic seeds of many angiosperm and gymnosperm plants (Sudhanshu Maheshwari et al., 2023).

Synthetic Seed – Synthetic seeds refer to plant tissues, such as somatic embryos, shoot buds, or cell clusters that have been artificially enclosed. These tissues are capable of germinating under both in vitro (in a controlled laboratory environment) and ex vitro (outside of a laboratory) settings. Furthermore, they retain this capacity even after being preserved. In the past, the phrase "artificial seeds" was used to describe somatic embryos that were economically feasible for moving plants to agricultural fields or green houses, as well



as for crop production (Grey & Purohit, 1991).

Synthetic seeds preparation

Somatic embryo development

While somatic embryogenesis has been observed in several crop species, the ability of somatic embryos to successfully develop into plantlets has been consistently low in terms of quality. This is due to the fact that somatic embryos typically exhibit inadequate development. Contrary to seed embryos, somatic embryos do not undergo the ultimate stage of embryo genesis known as 'embryo maturation'. However, in order for somatic embryos to mature, it was necessary to move them to a medium with a low concentration or no 2, 4-D. This was shown to be crucial according to Ammirato (1983), Cheema (1989), and Van der Valk et al. (1989). The embryos are transferred to a medium containing abscisic acid (ABA) in order to reach the last stage of development. ABA inhibits germination and facilitates proper embryo development by suppressing secondary embryogenesis. It has been documented to enhance embryo maturation in many species (Ammirato, 1983).

Encapsulation

Somatic embryogenesis is the sole clonal propagation mechanism that is economically feasible. Nevertheless, somatic embryos need robustness for the purpose of transplantation. Converting the in vitro encapsulated units (synthetic seeds) might be advantageous. The following are the fundamental prerequisites for the formation of synthetic seeds by encapsulation.

Explants used for encapsulation

Since the introduction of the synthetic seed technique, somatic embryos have been primarily used because they have the ability to develop both roots and shoots at the same time, thanks to the presence of the radical and plumule (Kitto and Janick,

1982, 1985 a, b; Kim and Janick, 1987, 1989, 1990; Janick et al., 1989; Redenbaugh et al., 1984; Redenbaugh et al., 1991b; Grey et al., 1991; Redenbaugh, 1993; McKersie and Bowley, 1993). Subsequent to that, various types of vegetative propagules have been observed in different plant species. For instance, shoot tips were found in *M. indica* (Bapat et al., 1987), axillary buds in *Camellia sinensis* (Mondel et al., 2002), calli in *Allium sativum* (Kim and Park, 2002), bulblets in *A. sativum* (Bekheet, 2006), nodal segments in *Pterocarpus marsupium* (Ahmad et al., 2023), nodal segments in *Salix tetrasperma* (Khan, 2018), somatic embryos in *Dalbergia latifolia* (Sharma, 2006), and nodal explants in *Populus alba* (Hussien et al., 2024).

Encapsulating agents

Researchers conducted tests on eight chemical compounds to determine their effectiveness in producing synthetic seed coverings. Among these compounds, the most suited agent for encapsulating somatic embryos was 'Polyox', a water-soluble resin (Kitto and Janick 1982, 1985c). According to Khan et al. (2018), they discovered that a solution of 3% (w/v) sodium-alginate with 100 mM calcium chloride was the best for producing homogeneous synthetic seeds. In a study conducted by Nor Asmah et al. in 2011, it was noted that when a 3% alginate with a concentration of 3% was used for encapsulation and subjected to combinations of 50 to 100 mM $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$, rounder beads were formed. Previous studies have examined various gelling agents, including polyox, polyco 2133, agar, agarose, alginate, carboxymethyl cellulose, carrageenan, guar gum, gelrite, tragacanth gum, sodium pectate, ethyl cellulose, nitrocellulose, and polyacrylamide, for the purpose of producing synthetic seeds (Ara et al., 2000; Saiprasad, 2001; Lambardi et al., 2006).



Synthetic endosperm

According to the general agreement, it is recommended that encapsulated synthetic seeds should include nutrients and plant development regulators, serving as a synthetic endosperm for the encased propagules. This is expected to improve the viability and germination efficiency of artificial seeds. The effectiveness of artificial seeds depends on the timely, high-quality, and precise supply of growth regulators and nutrients, together with an ideal physical environment (Senaratna, 1992). Artificial endosperm in *Morus* species was created using Murashige and Skoog medium (MS) without hormones and MS+ 6-benzyladenine (BA, 4.4 μ M), as described by Pattnaik et al. (1995) and Pattnaik and Chand (2000). In a study conducted by Mariani (1992), it was shown that the use of gibberellic acid (GA3) and sucrose had a detrimental impact on the germination of synthetic seeds in aubergine. Several researchers have documented that in incorporating fungicides (Antonietta et al., 2007b), pesticides, fertilisers, microorganisms (Rhizobia), mycorrhiza fungus (Tan et al., 1998), marine cyanobacterial extracts (Wake et al., 1992), bactericides, and activated charcoal (Ganapathi et al., 1992) in to the encapsulation solution can safeguard the enclosed propagules from microorganisms, decrease the release of harmful substances, and improve the seed's ability to germinate.

Encapsulation procedure

The hydro-gel encapsulation process established by Redenbaugh et al. (1987) is the most suitable approach for producing synthetic seeds. This method involved combining sodium alginate at different quantities (ranging from 2 to 5%) with calcium-free liquid MS medium. Afterwards, the explants were submerged in this solution. The explants were extracted using a pipette, together with the

sodium alginate solution, and then placed into a calcium chloride solution. Anion exchange event occurred, where sodium ions were replaced by calcium ions, leading to the creation of calcium alginate beads (Reddy et al., 2012). The entire procedure must be carried out in a sterile environment. The dimensions of the capsule are determined by the inner diameter of the pipette nozzle. The morphology and surface characteristics of the beads are contingent upon the concentration of sodium alginate, calcium chloride solutions, and the time of the complex at ion process. In 1993, Molle et al. proposed the use of a dual nozzle pipette, where the embryos flow through the inner pipette and the alginate solution flows through the outside pipette. Consequently, the embryos are strategically placed in the centre of the capsule to enhance their safety.

Germination and field planting

Synthetic seeds show potential as a viable alternative planting material for the forestry industry in the future, especially for species that are in high demand (Asmah et al., 2011). Artificial seeds provide the benefit of allowing the direct planting of plant propagules into the green house or field, thereby avoiding the need for many intermediate processes. In their study, Fujii et al. (1989) discovered that the use of ABA in the maturation process of lucerne somatic embryos resulted in a significant soil conversion rate ranging from 48% to 64%. The inclusion of a fungicide in the alginate beads serves to inhibit contamination and enhance the viability of mulberry buds when planted in soil (Bapat and Rao, 1990). However, Nor Asmah et al. (2011) found that the germination rate ranged from 73.3% to 100% during a period of 6 to 20 days.

Advantages of synthetic seeds

1. It is feasible to sow seeds directly in ex vitro settings.
2. Plant tissue culture is an optimal



- method for the ongoing creation of synthetic seeds.
3. Synthetic seeds are well-suited for distribution.
4. It is feasible to store items in a cold environment.
5. In contrast to natural seeds, artificial endosperm may be altered.
6. Double-layer encapsulation might offer additional protection.
7. In vitro, somatic embryos can be efficiently generated.
8. Non-embryo nictiss ues can be immediately used for syn seeds.
9. Hydrated gels are beneficial for encapsulating purposes.
10. Algin ate is the optimal choice for a coating substance.
11. Desiccation can extend the shelf life of syn seeds.

Trend of synthetic seeds in forestry

Table1: showing trend of synthetic seeds in forestry

Name of the species	Type of explant	References
<i>Dendrocalamu sstrictus</i>	Somatic embryos	Mukunthakumar and Mathur, 1992
<i>Santalum album L.</i>	Somatic embryos	Bapat and Rao, 1988 Bapat and Rao, 1992; Bapat, 1993
<i>Eucalyptus citriodora</i>	Somatic embryos	Muralidharan and Mascarenhos, 1995
<i>Hopea parviflora</i>	Somatic embryos	Sunilkumar et al., 2000
<i>Paulownia elongata</i>	Leaf and nodal segments	Ipekci and Gozukirmizi, 2003
<i>Quercus robur</i>	Somatic embryos	Prewein and Wilhelm, 2003
<i>Pinus patula</i>	Somatic embryos	Malabadi and Staden, 2005
<i>Dalbergia latifolia</i>	Somatic embryos	Sharma, 2006
<i>Pinus radiata</i>	Somatic embryos	Aquea et al., 2008
<i>Quercus suber</i>	Somatic embryos	Pintos et al., 2008
<i>Sterculia urens</i>	Nodal segments	Devi et al., 2014
<i>Terminalia arjuna</i>	Nodal segments	Gupta et al., 2014
<i>Salix tetra sperma</i>	Nodal segments	Khan, 2018
<i>Celastrus paniculatus</i>	Shoot tips	Fonseka et al., 2019
<i>Casuarina equisetifolia</i>	Shoot tips	Ahmad et al., 2022
<i>Pterocarpus marsupium</i>	Nodal segments	Ahmad et al., 2023
<i>Populus alba</i>	Nodal explants	Hussien et al., 2024

Conclusions

The synthetic seed technique is employed to achieve vegetative propagation and long-term preservation of exceptional germplasm from rare, endangered, and fragile species. This approach has the ability to revive plant species that possess valuable elite germplasm, which holds significant economic and medicinal worth for future generations. Moreover, the synthetic seed technology may be

employed to grow plant species that are capable of producing seeds, commonly referred to as seed less species. The development of synthetic seeds, which include the direct propagation of plant material from nurseries to fields, is crucial for transferring high-quality plant material between commercial and public laboratories. It also allows for the safe transportation of plant material across borders without the risk of spreading



diseases through aseptic pathways. Further investigation is required to enhance the capacity of artificial seed culture in a commercial substrate and in conditions that are not sterile. Artificial seeds are highly versatile and may be used extensively for propagating plants on a big scale. For many decorative and no longer existing plant species, it is the sole method of reproduction. In addition to this, they have been utilised in the commercial cultivation of autogamous plant species, genetically modified plants, conifers, algae, and other organisms. Overall, artificial seed technology has had a significant impact on all areas of plant biotechnology and has the potential to become the most promising and practical technology for the mass production of plants.

Future prospects

Historically, the emphasis in plant tissue culture publications has been on proliferation techniques, with little attention given to conservation, storage, and transit issues. Synseed technology has developed in the last three decades in an effort to surpass these constraints and enables the efficient production on a big scale. Nevertheless, the efficacy of a propagation technique does not guarantee the prosperous regeneration of synseeds, since variables like the selection of nursery medium, storage temperature, and time significantly influence the outcome. Integrating research on somatic embryo formation with synseed creation in a proper manner might effectively reduce the impact of limiting variables. Non-embryonic meristematic tissues have a high potential for synseed generation, which can make the storage and transfer of germplasm cost-effective for commercial uses. Furthermore, it is crucial to take into account the chemical composition of gel matrices and formulations of artificial endosperm when considering the use of

synseed technology for large-scale germplasm conservation

References

- Ahmad, Z., Yadav, V., Shahzad, A., Emamverdian, A., Ramakrishnan, M., & Ding, Y. (2022). Micropropagation, encapsulation, physiological, and genetic homogeneity assessment in *Casuarina equisetifolia*. *Frontiers in Plant Science*, 13, 905444.
- Antonietta Aiello, M., Leone, M., & Pecce, M. (2007). Bond performances of FRP bars-reinforced concrete. *Journal of materials in civil engineering*, 19(3), 205-213.
- Ara, H., Jaiswal, U., & Jaiswal, V. S. (2000). Synthetic seed: prospects and limitations. *Current science*, 1438-1444.
- Asmah, H.N., Hasnida, H.N., Zaimah, N.N., Noraliza, A., & Salmi, N.N. (2011). Synthetic seed technology for encapsulation and regrowth of in vitro-derived *Acacia* hybrid shoot and axillary buds. *African Journal of Biotechnology*, 10(40), 7820-7824.
- Aquea, F., Poupin, M.J., Matus, J.T., Gebauer, M., Medina, C., & Arce-Johnson, P. (2008). Synthetic seed production from somatic embryos of *Pinus radiata*. *Biotechnology letters*, 30, 1847-1852.
- Chandra, K., Pandey, A., & Kumar, P. (2018). Synthetic seed—Future prospects in crop improvement. *Int. J. Agric. Innov. Res.*, 6, 120-125.
- Capuano, G., Piccioni, E., & Standardi, A. (1998). Effect of different treatments on the conversion of M.26a poplar rootstock synthetic seeds obtained from encapsulated apical and axillary micropropagated buds. *The Journal of Horticultural Science and Biotechnology*, 73(3), 289-297.
- Devi, P.S., Satyanarayana, B., Arundhati, A., & Rao, T.R. (2014). Plant regeneration from encapsulated nodal



- segments of *Sterculia urens* Roxb., an endangered gum-yielding tree. *Journal of crop science and biotechnology*, 17, 21-25.
- Fonseka, D. L. C. K., Wickramaarachchi, W. W. U. I., & Madushani, R. P. S. (2019). Synthetic seed production as a tool for the conservation and domestication of *Celastrus paniculatus*: a rare medicinal plant. *Annual Research & Review in Biology*, 32(4), 1-8.
- Gantait, S., Kundu, S., Ali, N., & Sahu, N. C. (2015). Synthetic seed production of medicinal plants: a review on influence of explants, encapsulation agent and matrix. *Acta Physiologiae Plantarum*, 37, 1-12.
- Ganapathi, T. R., Srinivas, L., Suprasanna, P., & Bapat, V. A. (2001). Regeneration of plants from alginate-encapsulated somatic embryos of banana cv. Rasthali (*Musa* spp. AAB group). *In Vitro Cellular & Developmental Biology-Plant*, 37, 178-181.
- Garg, R., & Maheshwari, S. (2023). Synthetic seed technology, application and future trends. *EPH-International Journal of Agriculture and Environmental Research*, 9(1), 1-10.
- Gray, D. J., Purohit, A., & Trigiano, R. N. (1991). Somatic embryogenesis and development of synthetic seed technology. *Critical reviews in plant sciences*, 10(1), 33-61.
- Ipekci, Z., & Gozukirmizi, N. (2003). Direct somatic embryo genesis and synthetic seed production from *Paulownia longata*. *Plant cell reports*, 22, 16-24.
- Khan, M. I., Ahmad, N., Anis, M., Alatar, A. A., & Faisal, M. (2018). In vitro conservation strategies for the Indian willow (*Salix tetra sperma* Roxb.), a vulnerable tree species via propagation through synthetic seeds. *Biocatalysis and Agricultural Biotechnology*, 16, 17-21.
- Malabadi, R. B., & Staden, J. V. (2005). Storability and germination of sodium alginate encapsulated somatic embryos derived from the vegetative shoot apices of mature *Pinus patulata* trees. *Plant cell, tissue and organ culture*, 82, 259-265.
- Nongdam, P. (2016). Development of synthetic seed technology in plants and its applications: a review. *International Journal of Current Science*, 6(4), 86-101.
- Reddy, M. C., Murthy, K. S. R., & Pullaiah, T. (2012). Synthetic seeds: A review in agriculture and forestry. *African Journal of Biotechnology*, 11(78), 14254-14275.
- Sandoval-Yugar, E. W., Dal Vesco, L. L., Steinmacher, D. A., Stolf, E. C., & Guerra, M. P. (2009). Microshoots encapsulation and plant conversion of *Musa* sp. cv. 'Grand Naine'. *Ciencia Rural*, 39, 998-1004.
- Garg, R., & Maheshwari, S. (2023). Synthetic seed technology, application and future trends. *EPH-International Journal of Agriculture and Environmental Research*, 9(1), 1-10.
- Pintos, B., Bueno, M. A., Cuenca, B., & Manzanera, J. A. (2008). Synthetic seed production from encapsulated



- somatic embryos of cork oak (*Quercus suber* L.) and automated growth monitoring. *Plant Cell, Tissue and Organ Culture*, 95,217-225
- Singh, A. K., & Chand, S. (2010). Plant regeneration from alginate-encapsulated somatic embryos of *Dalbergia sissoo* Roxb.
- Sota, V., Benelli, C., Myrselaj, M., Kongjika, E., & Gruda, N. S. (2023). Short-Term Conservation of *Juglans regia* L. via Synthetic Seed Technology. *Horticulturae*, 9(5), 559
- Yücesan, B. (2019). Synseed: A new trend in seed technology. *Synthetic seeds: Germplasm regeneration, preservation and prospects*, 61-75.



Biochars from invasive biomass: Pine needles and *Lantana camara* for soil health

Ibajanai Kurbah¹, Sanjeev Kumar² and Rupam Nehta^{3*}

¹Department of Soil Science and Water Management, College of Forestry, Dr. Yashwant Singh University of Horticulture and Forestry NauniSolan, Himachal Pradesh, India

²Department of Basic Sciences College of Forestry, Dr. Yashwant Singh University of Horticulture and Forestry NauniSolan, Himachal Pradesh, India

³Department Fruit Science, College of Horticulture, Dr. Yashwant Singh University of Horticulture and Forestry NauniSolan, Himachal Pradesh, India

E-mail: rupamnehta777@gmail.com

Biochar is a carbon-dense, sponge-like product created through pyrolysis. Because of its great porosity, large surface area, chemical stability and large number of functional groups, biochar is an excellent amendment to improve soils. As an amendment, it provides increased water holding and aeration capacity, an increase of nutrients available to plants, as well as the ability to act as a long-term, stable carbon sink. Thus, biochar is a resource for improving the ability to maintain/restoring the fertility and resilience of soils. Furthermore, biochar can be used to remediate contaminated environments due to its ability to adsorb metals (e.g. cadmium, chromium, mercury, nickel and lead) (Uday et al., 2022; Maroušek et al., 2023) through the combination of surface functional groups, large surface areas, cation exchanging capacity and porous structure. Modified biochars enhance these attributes and have additional contributions to the process of enhancing carbon sequestration. Additionally, due to having a consistent supply of carbon and nutrients, biochar is a source of beneficial microorganisms, which in turn improves (cultivates) both the physical and biological aspects of soil (Hewitt et al., 2023). The accumulation of unwanted biomass, particularly pine needles and the invasive plant *Lantana*

camara, is making it increasingly difficult for hilltop residents in many parts of India to manage their forested and agricultural land. Pine needles accumulate on the ground, creating a very dry, thick layer that increases the risk of a forest fire and hinders reestablishment opportunities. *Lantana* is an extremely invasive shrub that grows rapidly to form dense stands that block sunlight from reaching the ground, thereby limiting the growth and biodiversity of native plants and reducing the ability of farmers and foresters to operate within these areas. Biochar produced from pine needles and *L.camara* is gaining recognition as a source for making high-quality biochars (Figure 01). Pine needles are light, porous and fibrous (contain high levels of lignin); therefore, they can help improve soil aeration and water retention.

How biochar is made

The biochar manufacturing process employs pyrolysis, a technique in which organic materials (biomass) are heated in an oxygen-starved environment using temperatures between 350°C and 600°C. Due to the absence of oxygen, complete combustion cannot occur, however, the biomass will undergo the process of carbonization instead of burning to an ash form of residue. In order to prepare the biomass (pine needles and *L.camara*), the



initial step is to chop and dry to an acceptable moisture level to allow for equal heating of all biomass, followed by placing it onto a heated surface in either a kiln or in a water bath styled biochar unit where the pyrolysis can be performed

accordingly. The process of pyrolysis generates volatile gases and vapors and these by-products are captured and utilized as a renewable source of energy; thus providing a sustainable and eco-friendly means of manufacturing biochar.

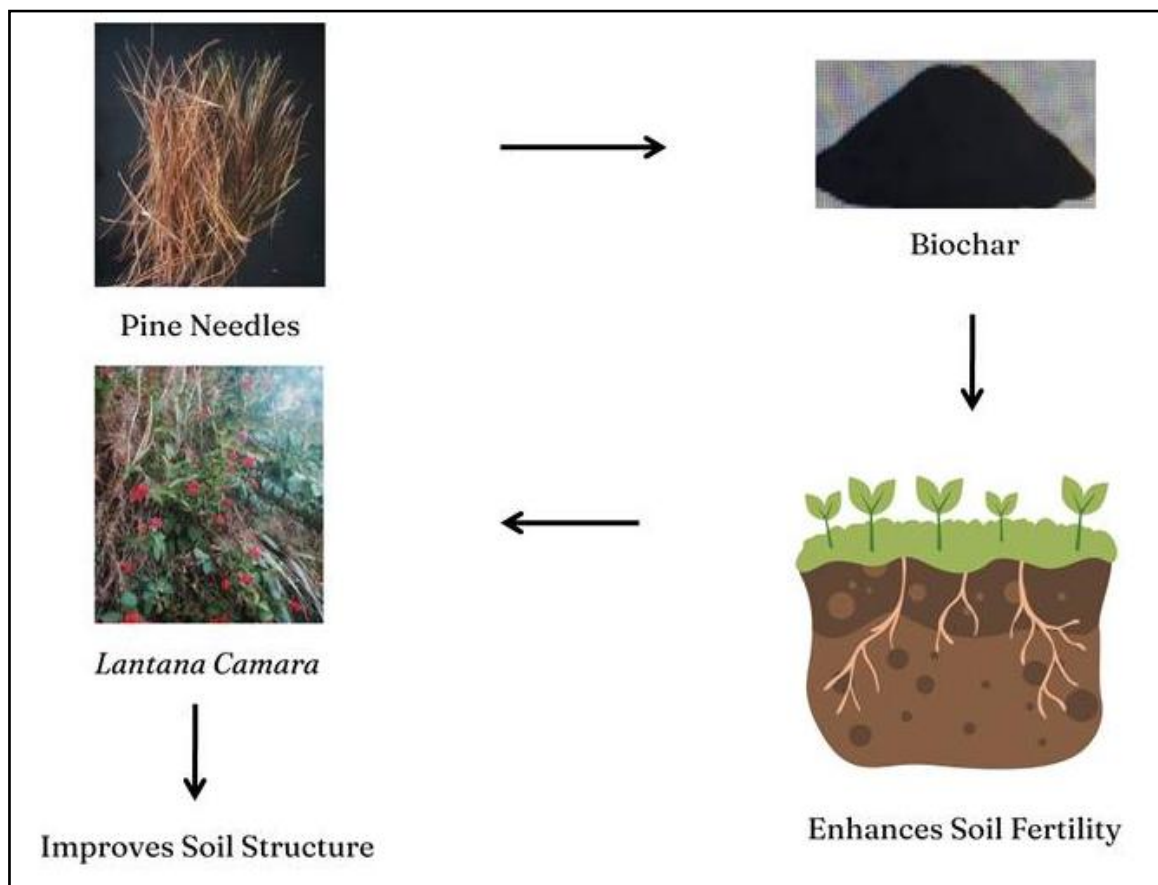


Figure 1: Biochars from Invasive Biomass: Pine needles and *Lantana camara* for Soil Health.

Why pine needles and *Lantana camara*?

Pine needles and *L. camara* are abundant and widely distributed in many hilly and forested regions of India. Despite their availability, both are often considered problematic biomass due to their environmental and management challenges. Every year, pine needles build up in a thick layer and create a level of biomass that can be extremely flammable and increase the risk of forest fires in hot,

dry weather to a much greater extent for areas that have such material present to approximately 0.89 million hectares within the Himalayan Region (Bisht and Thakur 2020). Pine wastes, which consist of needles, cones and wood, have a high composition of volatile compounds; thus, this biomass has a significant potential for the conversion to bio-oil and biochar through pyrolysis. Compared to other residual fuels, the higher volatile content,



lower ash percentage and elevated levels of carbon and hydrogen in pine residues make pine residues especially applicable to bioenergy production and biochar production of carbon-rich type. Additionally, the end product (biochar) produced from pine residues is deemed environmentally friendly, has a very high surface area, very high porosity, a significant quantity of functional groups and a high level of capacity for ionic exchange and has excellent stability and potential for reusability.

L.camara (L.) is an invasive shrub with an aggressive growth habit that forms impenetrable thickets. These thickets can suppress native plants, lower the overall biodiversity of areas where they invade, and impede agricultural and forestry practices. Largely due to its rapid continued growth and ability to survive in a wide variety of environmental conditions, *L.camara* is now one of the most problematic invasive species in the world (Sahoo et al., 2021). Unfortunately, an overwhelming majority of attempts to use the biological pathway to control *L.camara* have resulted in minimal success in suppressing its growth (Katembo et al., 2020). *L.camara* biomass is considered a valuable and sustainable resource for biochar due to its lower moisture and ash contents, but higher carbon content than other lignocellulosic materials like sawdust, rice husks, and cotton stalks (Havilah et al., 2019). It also has a large surface area, high cation exchange capacity and high pH. These qualities increase the ability of soils to supply and store nutrients effectively. When combined with compost or manures, it improves nutrient retention, reduces fertilizer

losses and increases soil fertility, making it a viable option for sustainable agriculture. Therefore, using *Lantana* for biochar production provides an opportunity for sustainable biomass management, promoting biodiversity conservation and landscape restoration through the development of systematic harvests of this invasive plant.

Advantages of turning pine needles and *Lantana camara* into Biochar

Eco-friendly waste management

Utilizing *Lantana* and Pine Needles as an economical resource for biochar helps to create a sustainable way to manage biomass. This method also minimizes the potential for wildfires within forests by removing combustible materials from the forest floor, as well as controlling invasive plant growth through using *Lantana* biomass.

Soil health improvement

Soil benefits greatly from biochar because of its honeycomb-like structure and ability to store water, especially in dry soils or degraded soils. Increasing the air pocket size and increasing the ability of microbes to survive and thrive are both created by the increased porosity from the use of biochar in relation to soil.

Carbon sequestration

The ability of biochar to store carbon for decades and centuries is one of its most significant environmental benefits. Because of its chemical stability compared to other organic amendments, which decompose rapidly, carbon in biochar has been locked up in the soil. This long-term storage option helps to mitigate climate change by reducing carbon dioxide emissions into the atmosphere due to the stability of this type of amendment. Thus,



while biochar is considered an amendment to improve soil fertility, it serves as an important ally for sustainable agriculture and climate-smart agriculture practices.

A sustainable opportunity for hill agriculture

There are many challenges that face both the Himalayan regions. These include soil erosion, a decrease in soil fertility, forest-type fire problems and an increase in unwanted, invasive weed species. The production of biochar from a combination of common biomass like pine needles and *L.camara* offers a viable and sustainable solution to these challenges. By turning problem-generating biomass into a valuable resource that helps improve soils, communities will have cleaner forests, improved soil fertility, less risk of wildfires and more sustainable agricultural production. Moreover, biochar production can create employment opportunities for small scale local commercial ventures, resulting in positive impacts for both the environment and the economy in rural communities located in hilly areas.

Conclusion

The environmental issue of managing invasive species and fire hazards can be addressed through the use of biochar made from pine needles and *Lantana camara*, resulting in sustainable agricultural practices and increased crop production. Converting these materials into a beneficial soil structure will help to improve soil health, which results in greater crop yields. As such, the development of more advanced technologies for the production of biochar will enable greater awareness of the importance of improving soils, meeting the needs of local communities and

developing healthy ecosystems in hilly regions where soils are more susceptible to erosion and degradation.

References

- Bisht, A.S. and Thakur, N.S., 2020. Pine Needles Biomass Gasification Based Electricity Generation for Indian Himalayan Region: Drivers and Barriers. pp. 47–59.
- Havilah, P.R., Sharma, P.K. and Gopinath, M., 2019. Combustion characteristics and kinetic parameter estimation of *Lantana camara* by thermogravimetric analysis. *Biofuels-Uk* 10, 365–372.
- Hewitt, S., Ghogare, R., Troxel, W., Tenic, E., Isaac, D. and Dhingra, A. 2023. Metatranscriptomic Analysis of Tomato Rhizospheres Reveals Insight into Plant-Microbiome Molecular Response to Biochar-Amended Organic Soil. *Front. Anal.Sci.*, 3, 1205583.
- Katembo, N., Witkowski, E.T.F., Simelane, D.O., Urban, A.J., Byrne, M.J., 2020. Impact of biocontrol agents on *Lantana camara* in an inland area of South Africa. *BioControl* 65, 143–154.
- Maroušek, J., Minofar, B., Maroušková, A., Strunecký, O. and Gavurova, B., 2023. Environmental and economic advantages of production and application of digestate biochar. *Environ. Technol. Innov.* 30, 103109
- Sahoo, A., Kumar, S., Kumar, J., Bhaskar, T. 2021. A detailed assessment of pyrolysis kinetics of invasive lignocellulosic biomasses (*Prosopis juliflora* and *Lantana camara*) by thermogravimetric



analysis. *Bioresour. Technol.* 319, 124060-124060.
Uday, V., Harikrishnan, P.S., Deoli, K., Zitouni, F., Mahlkecht, J., Kumar, M. 2022. Current trends in

production, morphology, and real-world environmental applications of biochar for the promotion of sustainability. *Bioresour. Technol.* 359, 127467



Pongamia pinnata (L.) Pierre: A tree of many uses

SoboroKomal¹, N. Ramakrishna¹, Yerkala Kumar¹, PottepakaShravan¹, GaddamSudharshan Reddy², *
ModalaRakesh³

¹Department of Botany, Dr. B.R. Ambedkar Open University, Hyderabad- 500033

²ICFRE – Institute of Wood Science and Technology, Bangalore-560003

³ICFRE – Forest Research Institute, Kaulagarh Road, Dehradun-248195

E-mail: rmodhal2021@gmail.com

Abstract

Pongamia pinnata (L.) Pierre, commonly known as Karanja or Indian Beech, is a multipurpose leguminous tree valued for its ecological, medicinal, and economic significance. Native to the Indian sub-continent and widely distributed across tropical and subtropical regions, this species has long been integrated into traditional medicine, agroforestry, and sustainable energy systems. Various plant parts leaves, bark, roots, and flowers, pods, and seeds possess distinctive therapeutic and industrial applications. The leaves and bark exhibit potent antimicrobial, anti-inflammatory, and antioxidant activities, while the seed oil, rich in oleic acid, serves as a promising source for biodiesel and biopesticide production. Ecologically, *P. pinnata* enhances soil fertility through nitrogen fixation, prevents erosion with its robust root system, and thrives in degraded or saline environments, making it an ideal candidate for reforestation and land reclamation. Additionally, its carbon sequestration potential and adaptability contribute to climate change mitigation and ecosystem restoration. Economically, the plant supports renewable energy industries, organic farming, and rural livelihoods through its diverse products such as karanja oil, green manure, and natural pesticides. This comprehensive review synthesizes the multifaceted roles of *Pongamia pinnata*, highlighting its

potential as a sustainable bioresource that bridges the gap between environmental conservation, traditional healthcare, and green economy development.

Keywords: *Pongamia pinnata*, Karanja, Biodiesel, Nitrogen fixation, Medicinal plants, Sustainable development, Bioresource

Introduction

Plants have been identified as an abundant and valuable source for the development of potential resources. *Pongamia pinnata* (Linn.) Pierre popularly known as Indian pongamia, Indian beech, Karanja, mullikulam tree, karumtree, pongam oil tree, seashore mempari is a medium-sized leguminous tree that is nearly evergreen with a short bole and spreading crown found in throughout the India and further eastward, primarily in the littoral regions of South Eastern Asia and Australia (Satyavati et al., 1987). This legume tree that has historically served in India and adjacent nations as a source of traditional medicine, green manure, timber, animal feed, fuel, biopesticide, and piscicide (Islam et al., 2021). In Indian ayurvedic literature, different portions of this plant have been prescribed as a treatment for various diseases. This plant's seed and oil have been used to treat a variety of inflammatory and infectious disorders, including leucoderma, leprosy, lumbago, and muscular and articular rheumatism (Nadkarni, 1954). The leaves are heated,



digestive, laxative, and anthelmintic, and they treat piles, wounds, and other inflammations (Kirtikar and Basu, 1933). A hot infusion of leaves is used as a medicinal bath to relieve rheumatic symptoms and to clean ulcers caused by gonorrhea and scrofilous growth (Chopra et al., 1933; Satyavati et al., 1987). Ecologically, *P. pinnata* plays a vital role in maintaining environmental balance through soil enrichment, carbon sequestration, and restoration of degraded ecosystems. Its ability to fix atmospheric nitrogen through symbiotic associations with *Rhizobium* bacteria improves soil fertility and promotes the growth of associated vegetation (Kumar & Sharma, 2011). The species is highly tolerant to drought, salinity, and heavy metal contamination, making it an ideal candidate for reforestation, land reclamation, and phytoremediation programs (Kaushik & Kumar, 2004; Dwivedi et al., 2011). Additionally, *P. pinnata* serves as an important biodiesel source, offering a sustainable alternative to fossil fuels and reducing greenhouse gas

emissions (Naik et al., 2008). Its dense canopy and extensive root system help prevent soil erosion, enhance groundwater recharge, and provide shade and habitat for a variety of fauna (Sujatha et al., 2008). This review evaluates the multiple ecological strengths and environmental functions of *P. pinnata*, highlighting its role as a key species in sustainable land management and climate change mitigation. Promoting its cultivation can make a substantial contribution to enhancing ecosystem resilience, conserving biodiversity, and improving rural livelihoods.

Distribution of *Pongamia pinnata*

In India found in Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, and Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal.

Found in other countries such as Bangladesh, Myanmar, Nepal, Thailand, Australia, China, Egypt, Fiji, Indonesia, Japan, Malaysia, Mauritius, New Zealand, Pakistan, Philippines, Seychelles, Solomon Islands, Sri Lanka, Sudan, United States of America (Pandey et al., 2019).

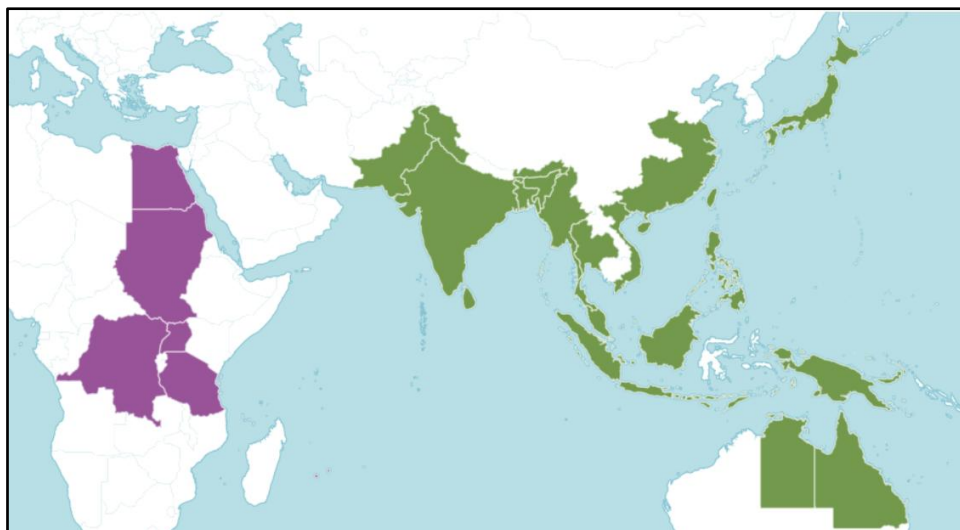


Figure 1: Distribution Map of *Pongamia pinnata* (Karanja) across the world.

(Source: <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:515679-1>)



The tree as a whole

The *P. pinnata* tree typically reaches 12–18 meters in height and features a spreading crown with a dense canopy of glossy green leaves. It thrives in tropical and subtropical climates and can tolerate saline, alkaline, and drought-prone soils. Being a legume, it forms a symbiotic relationship with *Rhizobium* bacteria in its root nodules, enabling nitrogen fixation that enriches the soil. Because of this property, the tree is extensively planted in agroforestry, reforestation, and land

reclamation projects. It prevents soil erosion, restores fertility, and contributes to carbon sequestration, making it an excellent species for sustainable environmental management.

In addition, *Pongamia* is valued for its ability to grow on marginal and degraded lands, where few other crops can survive. Its dense shade, strong root system, and resistance to pests make it a dependable tree for farm boundaries, roadways, and coastal belts.



Figure 2: *Pongamia pinnata* (a) Leaf; (b) Bark; (c) Tree.

Leaves

The leaves of *P. pinnata* are compound, shiny, and dark green, exuding a characteristic fragrance when crushed. They possess significant medicinal properties and are widely used in traditional Ayurvedic and folk medicine.

Medicinal uses

Heated leaves are used as poultices to relieve inflammation, swelling, and rheumatic pain. Decoctions made from the leaves act as a digestive aid, laxative, and anthelmintic (worm expeller). A hot infusion of leaves is used for bathing in cases of skin infections, ulcers, and gonorrhoea. Recent pharmacological studies have shown that leaf extracts possess antimicrobial, anti-inflammatory, and

antioxidant properties, validating their traditional applications.

Agricultural uses

The leaves, when used as green manure, enrich soil nitrogen and organic matter. They are also applied as a natural pest repellent in stored grains and gardens, thanks to their bioactive compounds like karanjin and pongamol.

Bark

The bark of *P. pinnata* is thick, gray-brown, and rough to the touch, rich in tannins and flavonoids.

Medicinal uses

In traditional medicine, bark extracts are used to treat bleeding piles, ulcers, and skin diseases. The bark decoction serves as a febrifuge (fever reducer) and is applied



externally to cleanse wounds and ulcers. Its anti-inflammatory and antimicrobial activity has been scientifically confirmed in recent studies.

Industrial uses

The bark contains tannins that can be used in leather tanning and dyeing processes. Its fibrous texture also makes it useful for making coarse ropes and mats in rural settings.

Roots

The roots of *P. pinnata* penetrate deep into the soil, stabilizing the ground and preventing erosion, especially along riverbanks and coastal areas.

Medicinal uses

Root extracts are used to treat gout, rheumatism, and ulcers, and they exhibit analgesic and anti-ulcer properties.

Ecological role

The root nodules host *Rhizobium* bacteria, which fix atmospheric nitrogen into the soil, improving fertility and supporting the growth of other crops. This symbiosis makes *Pongamia* a valuable companion species in agroforestry systems.

Flowers

The flowers are small, fragrant, and pinkish-white to lavender in color, blooming profusely during spring and early summer.

Medicinal and ecological uses

Flower extracts are known to have antidiabetic and antimicrobial properties. They attract bees and other pollinators, thereby supporting biodiversity and honey production.

Aesthetic value

The ornamental appeal of its blossoms makes it a popular choice for avenue planting and landscape beautification.

Pods and seeds

The pods are flat and contain one or two seeds that are oily and bitter in taste. These seeds are the most economically important part of the tree.

Economic uses

The seeds contain 30–40% oil, known as karanja oil, which is non-edible but rich in oleic acid. It is widely used in biodiesel production, biopesticides, and industrial lubricants.

The residual seed cake, after oil extraction, is used as organic manure and can be detoxified for use as animal feed.

Medicinal uses

Seed oil has been used traditionally for skin diseases, leprosy, and rheumatism due to its antimicrobial and anti-inflammatory properties. It is applied externally to treat eczema, scabies, and ulcers.

Oil (Karanja Oil)

Extracted from the seeds, karanja oil is a dark yellow to brown liquid with a distinctive odor.

Industrial and Economic Uses: It serves as a renewable source of biodiesel, meeting ASTM and European fuel standards. The oil is also used in the manufacture of soaps, candles, paints, and lubricants.

Medicinal and agricultural uses

:Karanja oil is applied as a natural pesticide and insect repellent in organic farming. It has proven efficacy against various agricultural pests and mosquito larvae. Medicinally, the oil is used topically for treating skin ailments, wounds, and joint pain.

Ecological Significance

Apart from its utilitarian uses, *P. pinnata* contributes immensely to the environment. It improves soil health, reduces carbon emissions through biodiesel substitution, and enhances biodiversity by providing



food and shelter to insects and birds. Its adaptability to saline and degraded soils makes it a pioneer species for land reclamation and climate resilience.

A comprehensive review on its ecological, medicinal, and economic potential

Ecological potential

Gunaseelan et al. [2014] studied the potential of biogas (CH₄) production from NaOH-treated and untreated biomass waste of *P. pinnata*. The results indicated that the maximum amount of methane was produced from untreated seeds, whereas a lower methane yield was obtained from the withered yellow leaves of *P. pinnata*. The methane yields from fiber-rich leaves and pod husks increased by 8–14% when treated with NaOH. The de-oiled cake of *P. pinnata* cannot be directly used for animal feeding or agricultural purposes due to its toxic properties. Hence, anaerobic digestion of oilseed cakes serves as an effective method for their safe disposal and energy recovery, producing a higher quality biogas compared to cattle dung alone. Moreover, co-digestion of cattle dung with *Pongamia* seed cakes significantly enhanced the digestion rate and methane yield. The C/N ratio of *P. pinnata* oilseed cake was found to be 34.4, while the pH ranged between 7.1 and 7.5, depending on the proportion of cattle dung, cake, and water dilution ratio used.

A 2006 field study reported that, over a 25-year growth period, a single *Pongamia* tree has the potential to sequester about 767 kg of carbon. The researchers also examined a large-scale implementation in Powerguda village, Adilabad district, Telangana, India, where 3,600 *Pongamia* trees were planted to assess their combined

carbon sequestration capacity (Degani et al., 2022).

Tulod et al. conducted a detailed investigation to evaluate the growth performance and phytoremediation potential of *Pongamia pinnata*, *Samanea saman*, and *Vitex parviflora* in copper-contaminated soil amended with zeolite and vesicular arbuscular mycorrhiza (VAM) over a 170-day growth period. The study aimed to assess the combined influence of these soil amendments on the plants' growth, biomass production, and copper uptake.

Medicinal potential

(Sajid et al., 2012) conducted a pioneering investigation into the variations in biological activities among the bark, leaves, and seeds of *P. pinnata*, focusing on their antioxidant and antimicrobial potential using a range of solvent extraction methods. This study represented the first systematic attempt to compare the bioactive properties of different plant parts of *P. pinnata* across multiple extraction solvents. The results suggested that the bioactive constituents of *P. pinnata* could serve as lead molecules for developing new antimicrobial drugs and functional foods designed to promote human health.

(Manigauha et al., 2009) explored the neuropharmacological potential of *P. pinnata*, a plant traditionally used in Indian medicine for the treatment of mental ailments and as a brain tonic. The authors investigated the anticonvulsant and neuroprotective properties of the plant and its bioactive constituent karanjin, providing important insights into its possible therapeutic role in neurological disorders.



(Srinivasan et al., 2001) conducted a comprehensive study to evaluate the anti-inflammatory potential of *P. pinnata* leaf extracts using acute, subacute, and chronic inflammation models in rats. The authors administered a 70% ethanolic extract of *P. pinnata* leaves and examined its effects on different experimental models of inflammation to determine both its efficacy and safety.

(Dwivedi et al., 2017) investigated the gastroprotective and ulcer-healing potential of the methanolic root extract of *Pongamia pinnata* in experimental animal models. After 10 days of treatment, the methanol extract demonstrated significant protection against aspirin-induced mucosal damage and a marked reduction in acetic acid-induced ulcers in Wistar rats. The findings indicated that *P. pinnata* root extract exhibits ulcer-protective effects, primarily by enhancing mucosal defence mechanisms.

Economical potential

Scott et al. conducted an extensive study on the potential of *P. pinnata* as a sustainable feedstock for biodiesel production. Their research highlighted that the seeds of *P. pinnata* contain 30–40% oil, which can be efficiently converted into biodiesel (fatty acid methyl esters, FAMES) through esterification with methanol in the presence of potassium hydroxide (KOH). The authors analysed the fatty acid composition of the seed oil and reported that oleic acid (C18:1) is the dominant component, constituting 40–55% of the total fatty acids. The study noted that while unsaturated C18 acids such as C18:2 and C18:3 is more prone to oxidation, the overall composition of *P. pinnata* oil makes it a suitable and stable

source for biodiesel. The fuel properties of *P. pinnata* biodiesel were found to meet North American and European standards, demonstrating its quality and viability as a renewable fuel.

Conclusion

P. pinnata stands as an exceptional example of nature's multifunctionality combining ecological resilience, medicinal richness, and economic promise. Its diverse phytochemical profile underpins a wide spectrum of pharmacological effects, including anti-inflammatory, antimicrobial, antioxidant, and neuroprotective properties, which substantiate its deep-rooted role in Ayurvedic and traditional medicine. Ecologically, its nitrogen-fixing ability, tolerance to saline and degraded soils, and contribution to carbon sequestration render it an invaluable species for environmental rehabilitation and climate-smart land management. Economically, *P. pinnata* represents a viable renewable energy crop due to its high oil yield suitable for biodiesel production, aligning with global efforts toward reducing fossil fuel dependency and carbon emissions. Further, strengthens its role in circular bioeconomy models. Promoting large-scale cultivation of *P. pinnata* can enhance rural income, support sustainable industries, and restore ecological balance. Future research should focus on genetic improvement, value-added processing, and optimized agroforestry integration to fully harness the potential of this remarkable tree for a greener, more sustainable future.

References

Azam, M. M., Waris, A., & Nahar, N. M. (2005). *Prospects and potential of*



- fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India*. Biomass and Bioenergy, 29(4), 293–302.
- CABI Compendium, (2021). *Pongamia pinnata (Indian Beech)*. Plant Wise Plus Knowledge Bank.
- Chopra, R.N., Chopra, I.C., Handa, K.L., Kapur, L.D., (1933). *Indigenous Drugs of India*. Academic Publishers, Calcutta, p. 388.
- Degani, E., Prasad, M. V. R., Paradkar, A., Pena, R., Soltangheisi, A., Ullah, I., ... & Tibbett, M. (2022). A critical review of *Pongamia pinnata* multiple applications: from land remediation and carbon sequestration to socioeconomic benefits. *Journal of Environmental Management*, 324, 116297.
- Dwivedi, G., Jain, S., & Sharma, M. P. (2011). *Pongamia as a source of biodiesel in India*. *Renewable and Sustainable Energy Reviews*, 15(6), 4632–4641.
- Gunaseelan, V. N. (2014). Biogas production from *Pongamia* biomass wastes and a model to estimate biodegradability from their composition. *Waste Management & Research*, 32(2), 131–139.
- Islam, A.K.M.A., Chakrabarty, S., Yaakob, Z., Ahiduzzaman, M., Kalam Mohammad Mominul Islam, A., (2021). *Koroch (Pongamia pinnata): a promising Unexploited resource for the tropics and Subtropics*. In: Cristina Gonçalves, A., Sousa, A., Malico, I. (Eds.), *Forest Biomass - from Trees to Energy*. IntechOpen, London.
- Kaushik, N., & Kumar, K. (2004). *Karanja (Pongamia pinnata) based biodiesel: A promising substitute for petroleum diesel*. *Biomass and Bioenergy*, 26(6), 623–629.
- Kirtikar, K.R., Basu, B.D., 1933. *Indian Medicinal Plants*, vol. I. Lalit Mohan Basu, Allahabad, India, p. 830.
- Kumar, A., & Sharma, S. (2011). *Potential non-edible oil resources as biodiesel feedstock: An Indian perspective*. *Renewable and Sustainable Energy Reviews*, 15(4), 1791–1800.
- Manigauha A, Patel S, Monga J, Ali H (2009). Evaluation of anticonvulsant activity of *Pongamia pinnata* Linn in experimental animals. *International Journal of PharmTech Research*. 4:1119-1121.
- Nadkarni, K.M., (1954). *Indian Materia Medica*, vol. 1. Popular Book Depot, Bombay, India, p. 1001.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Simons, A. (2009). *Agroforestry Database: A tree reference and selection guide version 4.0*. World Agroforestry Centre, Nairobi, Kenya.
- Sajid, Z. I., Anwar, F., Shabir, G., Rasul, G., Alkharfy, K. M., & Gilani, A. H. (2012). Antioxidant, antimicrobial properties and phenolics of different solvent extracts from bark, leaves and seeds of *Pongamia pinnata* (L.) Pierre. *Molecules*, 17(4), 3917–3932.
- Satyavati, G.V., Gupta, A.K., Tandon, N., (1987). *Medicinal Plants of India*,



- vol. II. Indian Council of Medical Research, New Delhi, p. 490.
- Scott, P. T., Pregelj, L., Chen, N., Hadler, J. S., Djordjevic, M. A., & Gresshoff, P. M. (2008). *Pongamia pinnata*: an untapped resource for the biofuels industry of the future. *Bioenergy Research*, 1(1), 2-11.
- Srinivasan K, Muruganandan S, Lal J, Chandra S, Tandan SK, Ravi Prakash V (2001). Evaluation of anti-inflammatory activity of *Pongamia pinnata* leaves in rats. *Journal of Ethnopharmacology*. 78:151-157.
- Sujatha, M., Reddy, T. P., & Mahasi, M. J. (2008). *Role of biotechnological interventions in the improvement of Pongamia pinnata (L.) Pierre – A legume tree for biodiesel and value-added products*. *Asia-Pacific Journal of Molecular Biology and Biotechnology*, 16(1), 1–14.
- Tulod, A. M., Castillo, A. S., Carandang, W. M., & Pampolina, N. M. (2012). Growth performance and phytoremediation potential of *Pongamia pinnata* (L.) Pierre, *Samanea saman* (Jacq.) Merr. and *Vitex parviflora* Juss. in copper-contaminated soil amended with zeolite and VAM. *Asia Life Sci*, 21(2), 499-522.
- Pandey, P., Sharma, A., & Mca, S. (2019). A survey on *Pongamia pinnata* (karanj) with traditional, economical, medicinal use. *Journal of Emerging Technologies and Innovative Research*, 6(2): 1367-1372.



Stop pruning of wood-yielding trees (Teak and Sandalwood)- Grow morewood and use more wood

R. Sundararaj and Ramkumar V R

Institute of Wood Science and Technology (ICFRE - IWST)

Bengaluru

Email: ramce37@gmail.com

Pruning is the practice of removing specific parts of a tree or shrub that are drying or dying due to pests, diseases, or lack of sunlight. In public parks and gardens, trees are often pruned to control their shape and maintain structural integrity, thereby enhancing their aesthetic appeal (Fig. 1). Fruit farmers commonly prune trees such as mango, pomegranate, moringa, and mulberry after every harvest, often relying on unscientific methods and

unhealthy practices in an attempt to maximise yield within a short period. While pruning helps limit branch height and ensures easier access to leaves, flowers, and fruits, and can indeed boost productivity in the short term, these benefits come at the cost of the tree's overall lifespan and long-term health. However, many tree species also self-prune as part of their natural biological process.

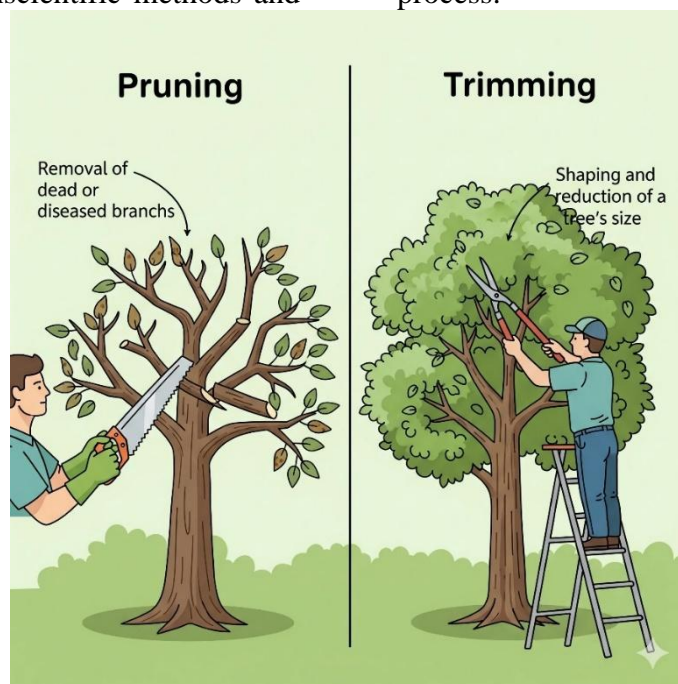


Fig 1: Pruning Vs Trimming

Unaware of this fact, farmers and timber growers often apply the same logic to teak and sandalwood, following misguided advice from professors and expert scientists, which ultimately causes greater harm to the tree (Fig 2 and Fig 3). So far, no scientific evidence has been reported to demonstrate the benefits of pruning in wood-yielding tree species. Pruning teak

and sandalwood trees can have serious negative consequences, including weakened structural integrity, stunted growth, and open wounds that invite diseases. It also removes vital flower and leaf buds, which may reduce tree vigor, compromise stability, and diminish both aesthetic value and ecosystem services (Fig 4 and Fig 5).





Fig 2: Tree pruning Before (2a) and after teak (2b)



Fig 3: Pruning cut made close to the main trunk

The bark serves as the tree’s first line of defense, protecting the inner stem layers — the sapwood beneath the bark and the heartwood at the core. When branches are pruned, this protective layer is wounded and dries out, leaving cut ends that expose the inner tissues. These open wounds

become easy entry points for biodeteriorating organisms such as wood-decaying fungi (*Allophomatropica*, *Ganodermaapplanatum*, *Xylariaberteri*) and pests like wood borers and termites, which first feed on the dried bark and then invade the exposed stem tissues. As decay



progresses, the inner layers deteriorate, weakening the tree structurally, reducing leaf size, and causing premature fruit drop. Pruning-induced injuries also disrupt

natural branch growth patterns, often leading to excessive bunching at specific points.

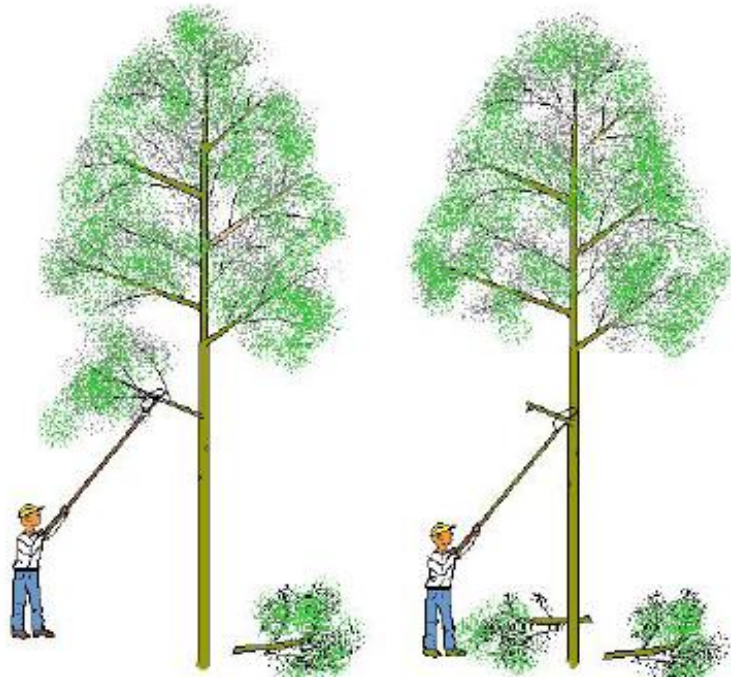


Fig 4: Cruelty to trees



Fig 5: Impact of pruning/wounding in teak trees





Fig 6: Trees are crying due to wounding/pruning





Fig 7: Pruning of sandal wood and its effects



Fig 8: Impact of pruning from death of sandalwood trees to loss of heartwood



Once fungal and insect infestations are established, they are extremely difficult to control, as many of these organisms have developed strong resistance to pesticides. Additionally, excessive pruning weakens structural stability by reducing leaf area and limiting photosynthesis, thereby depleting the tree's energy reserves and making it more vulnerable to strong winds (Fig 4 and Fig 6). In many cases, heavily pruned trees require wooden props for support, which themselves attract termites when dry, further accelerating decline. Beyond structural and physiological impacts, pruning disrupts ecological interactions by reducing flower and leaf bud availability, limiting essential resources for pollinating insects. This affects their foraging, nesting behaviour, phenology, and reproduction, ultimately harming cross-pollinating tree species such as teak and sandalwood.

The Institute of Wood Science and Technology (IWST) has conducted an analysis of timber plantations across five states - Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, and Telangana. The study revealed that a major cause of economic loss to timber growers is the unnecessary pruning of valuable timber species such as teak and sandalwood (Fig 7 and Fig 8). The findings strongly emphasize that: "The so-called 'Science of Pruning' becomes the 'Philosophy of Destruction' when applied to long-rotation, high-value timber trees." The southern states are leading producers of sandalwood and teak, both of which hold significant ecological and commercial value. Their cultivation, particularly in Karnataka and Tamil Nadu, expanded rapidly in the early 2000s when private ownership was legalized. These species

are highly profitable: on average, a well-maintained sandalwood tree can yield around ₹1 lakh in 15 years and up to ₹5 lakhs in 25 years, provided its health is safeguarded.

However, many growers fail to achieve such returns. Premature tree mortality and poor growth performance are frequently observed, and evidence points to pruning as the root cause. By reducing leaf cover, pruning weakens the tree's physiological functions, stunts growth, and compromises its survival.

Therefore, growers of long-rotation timber species must abandon this misguided practice and instead focus on maintaining tree health through natural, sustainable growth-enhancing methods. A clear distinction must be made:

- We get benefits by pruning fruit crops (grown for food).
- We lose the trees and their production by pruning timber trees (grown for wood).

Every leaf is vital—not only for the tree's growth but also for the ecosystem services it provides. In the era of climate change, the urgent call is: "Save durable, long-rotation timber trees from pruning. Love the trees, and grow wood"

Preserving the integrity of these species is essential for sustaining their productivity, ensuring grower profits, and conserving tree-based ecosystems for future generations. Pruning may aid fruit crops, but in timber trees like teak and sandalwood it weakens growth, shortens lifespan, and invites pests and diseases. Sustainable, non-pruning practices are essential to safeguard tree health, grower profits, and ecosystem resilience.



Bioprospecting: Creating value for biodiversity

Surabhi Sharma^{1*}, Kavita Kumari Thakur², Bhupender Dutt¹ and Rohit Sharma¹

¹Department of Forest Products

Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP 173230

²Department of Fruit Science

Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP 173230

E-mail: surabhisharma330@gmail.com

Bioprospecting is defined as a process of "exploration of biodiversity for commercially valuable biological and genetic resources". This endeavour "involves the application of advanced technologies to develop new pharmaceuticals, agrochemicals, cosmetics, flavourings, industrial enzymes, and other valuable products. Indigenous knowledge plays a crucial role in this process since traditional insights often provide valuable leads to bioresources with commercial potential. The convergence of scientific knowledge and traditional wisdom has further highlighted the importance of genetic resources.

Bioprospecting entails the search, identification, and collection of biospecimens followed by the examination of their molecular, biochemical, or genetic properties. It also employs various cutting-edge technologies to process and develop genetic material from these specimens that possess desirable characteristics for commercial products (Cao and Kingston, 2009). However, the expanding market potential of natural products has sparked concerns about equitable benefit-sharing, sustainable resource use, and capacity building in developing nations. With its broad industrial relevance, bioprospecting continues to drive innovation by uncovering novel applications for biological species, significantly contributing to new product development in sectors such as healthcare, agriculture, and personal care (Afreen and Abraham, 2008).

Bioprospecting has historically played a crucial role in major medical discoveries, such as the cancer drug paclitaxel

(Taxol) derived from the Pacific yew tree (*Taxus brevifolia*) and the antimalarial compound artemisinin extracted from *Artemisia annua*. Although the term bioprospecting is modern, the practice itself dates back millennia, when early civilizations observed that certain plant roots possessed therapeutic properties or distinct flavours. A well-known example of accidental bioprospecting is Alexander Fleming's discovery of penicillin. Similarly, the active ingredient in willow bark, salicylic acid — a precursor to aspirin — had been used by the Greeks as early as the fifth century BC to alleviate fever and pain. Over time, scientific advancements enabled researchers to isolate, refine, and synthesize these bioactive compounds for broader medical applications. In recent years, the increasing demand for natural products and traditional medicine in pharmaceuticals has revived interest in bioprospecting, given its potential for drug development and herbal remedies. In the past two decades, rapid advancements in biotechnology, medicine, and agriculture have further expanded the scope and economic potential of bioprospecting, highlighting its importance in modern science.

Why Bioprospecting?

- To discover new natural resources and goods that humanity may utilize.
- The increasing global population demands innovative products and industrial processes, such as new drugs and medicines, to improve human health and nutrition



- Bioresources provide essential raw materials for meeting the demands of various industries like pharmaceutical, agricultural, cosmetic, food, and flavour industries.
- Required to find leads for drug development because there are either few known or current compounds for creating medications for human use, or some diseases are still incurable.

What is being used in bioprospecting?

Plants: Explored for their nutritional and medicinal properties

Animals: studied for their genetic traits and bioactive components.

Any other organism: Includes fungi, bacteria, and microorganisms with potential commercial value.

Derivative: part, tissue, extract, chemical compounds.

Genetic material: contains functional units of heredity, usually employed for research, breeding, or biotechnological advancements.

Who does bioprospecting?

Phases of bioprospecting

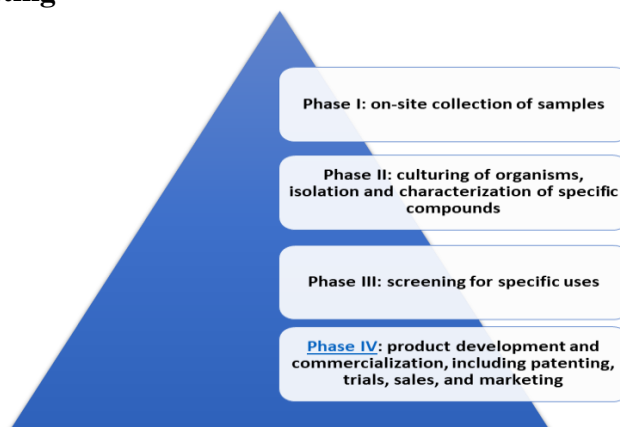


Figure 1: Four phases of bioprospecting

Bioprospecting is a multidisciplinary process that involves several scientific stages, each crucial for transforming natural bioresources into valuable commercial products.

- The initial step is collection, where biological materials are sourced

Bioprospecting involves several industries, including medicines, agribusiness, biotechnology, seed, crop protection, horticulture, cosmetics, personal care and fragrance, botanicals, and food and beverage. The majority of natural product research now takes place at academic and government research facilities, as well as smaller discovery enterprises (Afreen and Abraham, 2008).

Need for Exploring Natural Products

- Living organisms are valuable sources of natural products with significant chemotherapeutic potential.
- Tribal and folk remedies have effectively utilized these natural resources for centuries.
- Scientific research and therapeutic validation of natural products are ongoing to confirm their efficacy.
- Natural products often serve as essential starting points for developing improved medicinal compounds with enhanced properties.

from diverse ecosystems such as forests, deserts, aquatic systems, and geothermal vents. Culture collections, botanical gardens, and protected areas are also vital sources. An example is the discovery of Taq polymerase,



derived from *Thermus aquaticus*, found in Yellowstone National Park's geothermal springs, which revolutionized PCR technology (Chien et al., 1976).

- The next stage, screening, involves identifying bioactive compounds using advanced techniques like high-throughput screening (HTS) and metabolomics tools such as LC-MS, GC-MS, and NMR. These methods led to the discovery of Daptomycin, an antibiotic derived from *Streptomyces roseosporus* (Miao et al., 2005).
- Following identification, isolation and purification are carried out using techniques like solvent extraction and chromatography to obtain pure compounds. For example, Taxol (Paclitaxel), a powerful anticancer agent, was isolated from *Taxus brevifolia* through solvent fractionation and HPLC. Since some natural products have complex structures, semi-synthetic modifications are often required to enhance bioavailability and yield. An example is Artemisinin, a potent antimalarial derived from *Artemisia annua*, whose modified derivatives like artemether improved therapeutic efficacy.
- The subsequent phase includes clinical trials, where drugs undergo rigorous testing for safety, efficacy, and pharmacokinetics. Notably, Yondelis (trabectedin), sourced from the marine tunicate *Ecteinascidiaturbinata*, successfully passed trials and gained FDA approval as a cancer treatment (Cuevas and Francesch, 2009). In addition, field trials ensure practical effectiveness in agriculture and environmental management, such as bioherbicides

derived from *Alternaria cassiae* to control *Cassia obtusifolia* infestations.

- To secure innovations, intellectual property protection plays a crucial role. India's Traditional Knowledge Digital Library (TKDL) helps safeguard indigenous medicinal knowledge and prevent biopiracy.
- Finally, the manufacturing and marketing phase involves scaling up production with methods like fermentation, plant cell culture, and enzyme engineering ensuring product stability, quality, and cost-effectiveness. For instance, Lovastatin, a cholesterol-lowering drug from *Aspergillus terreus*, is mass-produced through optimized fermentation methods. Effective marketing strategies that emphasize sustainability further enhance product outreach and social impact.

Bioprospecting in Different Fields

Bioprospecting is a scientific process that explores biological resources to identify bioactive compounds with potential commercial applications. Plants, microbes, marine organisms, and terrestrial ecosystems each contribute unique chemical and genetic diversity, offering significant prospects in pharmaceuticals, agriculture, and industrial biotechnology.

Plant Bioprospecting

Plants are vital sources of bioactive compounds such as alkaloids, terpenoids, and flavonoids, known for their antimicrobial, anti-inflammatory, and antioxidant properties. Advances in extraction techniques, including solvent extraction, chromatography, and molecular screening, have improved the identification and isolation of plant-derived compounds. Sustainable harvesting practices and plant tissue culture methods are widely employed to conserve biodiversity while maximizing compound production (Newman and



Cragg, 2020). Modern techniques like metabolomics and genome-based screening further enhance the discovery of novel plant-based molecules.

Microbial Bioprospecting

Microbes are prolific producers of secondary metabolites, including antibiotics, immunosuppressants, and industrial enzymes. Bacteria, fungi, and actinomycetes have proven invaluable due to their rapid growth and adaptability, which facilitate scalable production. Advanced genomic tools such as metagenomics enable the identification of novel biosynthetic gene clusters that drive the discovery of previously unknown microbial metabolites (Charlop-Powers et al., 2016). Techniques such as fermentation optimization and genetic engineering have further improved microbial metabolite yields and bioactivity.

Marine Bioprospecting

Marine environments, characterized by extreme conditions like high pressure, low temperatures, and limited sunlight, foster the evolution of unique metabolic

pathways in marine organisms. This results in the production of structurally diverse bioactive compounds with novel mechanisms of action. Marine-derived metabolites are increasingly explored for their anticancer, antiviral, and anti-inflammatory potential. Genome mining and microbial cultivation techniques have improved the discovery and large-scale production of marine bioactive compounds.

Terrestrial Bioprospecting

Terrestrial ecosystems, particularly soil environments, are rich in microbial diversity, which is a valuable source of antibiotics and enzymes. Actinomycetes and other soil-dwelling bacteria contribute significantly to bioprospecting efforts. Additionally, terrestrial plants adapted to extreme environmental conditions often develop bioactive secondary metabolites with protective functions. Modern techniques like molecular phylogenetics and metabolic engineering have enhanced the identification and production of terrestrial bioactive molecules.

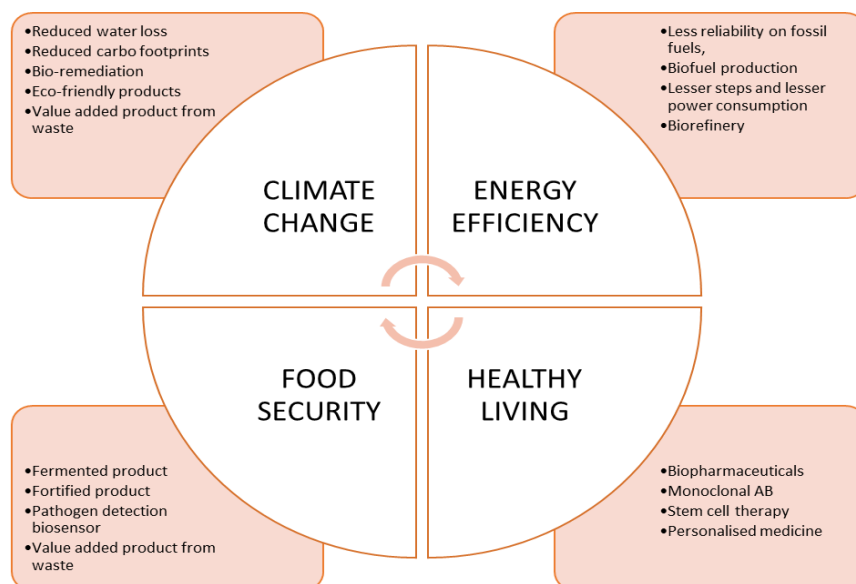


Figure 2: Bioprospecting: Harnessing Biodiversity for Pharmaceutical, Agricultural, and Industrial Advancements

Plants as a source of drugs

- Plants represent major approach for the discovery and development of

new drugs due to their chemical diversity and ability to act on various biological targets.



- Plant secondary metabolites played an important role in alleviating several ailments in traditional medicines and folk uses.
- Basis of many traditional medicine systems throughout the world for thousands of years.
- Initially dispensed in form of crude drugs such as tinctures, teas, poultices and herbal formulations.
- In modern medicine, they provided lead compounds for the production of medications.
- Drug discovery from plants involves a multidisciplinary approach combining botanical, ethnobotanical, phytochemical, biological and biotechnological techniques.

The classes of secondary plant metabolites include:

- Polyphenols
- Alkaloids
- Terpenes
- Saponins
- Glycosides

Screening of bioactive compounds

It is done mainly by 3 methods.

Random method

It involves random collection of plants found in the given area of study.

Phylogenetic method

It involves the collection and analysis of all the members of those plant families in which some taxa are already known to be good sources of useful products.

Ethno-directed method

It is mainly focused on plants which based on traditional knowledge or are known to be used by tribal people but not yet popularised.

The process of plant bioprospecting can be broadly classified into two categories

- Single plant species, where plants are selected on the basis of their folk use and screened for their biological activities (medicinal or agricultural) and chemical constituents. This approach led to the isolation of a large number of bioactive chemical constituents, many of which are in different stages of biological and pharmacological studies
- The second involves the rationalization of composite plant-based remedies and manufacturing of herbal-based medicines that are already in use. These projects include standardization of medicines, toxicological studies and bioassay screenings.

Table 1: FDA approved plant drugs

Drug	Source	Part	Nature	Use	Trade name
Atropine	<i>Atropa belladonna</i>	Leaves	Alkaloid	Anti- cholinergic	Atropen
Forskolin	<i>Coleus forskohlii</i>	Roots	Diterpene	For treating obesity	Colforsin, NKH477
Tubocurarine	<i>Chondrodendron tomentosum</i>	Bark	Alkaloid	Anaesthesia	Curopan
Reserpine	<i>Rauwolfia serpentina</i>	Roots	Alkaloid	Anti- hypertensive	Serpasil
Morphine	<i>Papaver somniferum</i>	Latex	Alkaloid	Analgesic	Duramorph
Digoxin	<i>Digitalis lanata</i> , <i>D. purpurea</i>	Leaves	Glycoside	Cardiotonic	Digitek



Vincristine and Vinblastine	<i>Catharanthus roseus</i>	Aerial parts	Alkaloid	Anti- cancer	Oncovin
Quinine	<i>Cinchona spp.</i>	Bark	Alkaloid	Anti- malarial	Quinstar
Paclitaxel	<i>Taxus spp.</i>	Bark and leaves	Alkaloid	Anti- cancer	Taxol
Galantamine	<i>Galanthus nivalis</i> , <i>G. caucasicus</i> , <i>G. woronwii</i>	Bulbs and flowers	Alkaloid	Anti- Alzheimer	Razadyne
Rivastigmine	<i>Physostigma venenosum</i>	Fruit	Alkaloid	For treating dementia	Exelon
Pilocarpine	<i>Pilocarpus jaborandi</i>	Leaves	Alkaloid	For treating glaucoma	Andre Carrpine
Colchicine	<i>Gloriosa superba</i>	Root	Alkaloid	Gout treatment	Colcrys

Table 2: Semi- synthetic derivatives of drugs

Drug	Semi- synthetic derivative
Paclitaxel	Docetaxel and cabazitaxel
Vincristine, vinblastine	Vindesine, vinorelbine and its bifluorinated analogue vinflunine.
Podophyllotoxin	Etoposide and teniposide.
Artemisinin	Artesunate, arteether and artemether
Morphine	Apomorphine, hydromorphine
Comptothecin	Irinotecan and topotecan
Atropine	Tiotropium

Bioprospecting in agriculture**Biopesticides and Bioherbicides*****Bacillus thuringiensis* (Bt) toxin**

A naturally occurring soil bacterium used to produce Bt crops (e.g., Bt cotton, Bt corn) that are resistant to insect pests like the cotton bollworm (*Helicoverpa armigera*).

Neem extracts (*Azadirachta indica*)

Neem-based pesticides (e.g., azadirachtin) act as natural insect repellents, disrupting pest growth cycles.

Metarhizium anisopliae

A fungus used in the biological control of insects like locusts and mosquitoes.

Biofertilizers***Rhizobium spp.***

Symbiotic nitrogen-fixing bacteria used in leguminous crops like soybeans, peas, and chickpeas to enhance soil fertility.

Azospirillum spp.

Free-living nitrogen-fixing bacteria that improve root development and nutrient uptake in cereals like wheat and maize.

Mycorrhizal fungi (*Glomus spp.*)

Enhance phosphorus uptake in crops such as corn, tomatoes, and fruit trees.

Plant growth promoters**Gibberellins from *Gibberella fujikuroi***

Used in horticulture to promote seed germination and stem elongation in crops like grapes and sugarcane.



Trichoderma spp.

Fungi that enhance root growth and provide protection against root diseases in vegetables and cereals.

Seaweed extracts (e.g., *Ascophyllum nodosum*)

Act as biostimulants to improve crop stress tolerance and yield.

Drought and disease resistance**Drought-resistant genes from *Tepary beans (Phaseolus acutifolius)***

Used in breeding drought-tolerant common beans.

Wild wheat (*Aegilops tauschii*)

Source of disease-resistant genes used in modern wheat varieties to combat rust diseases.

Tomato wild relatives (*Solanum pennellii*)

Used to introduce salt and drought resistance in cultivated tomatoes.

Soil Health***Pseudomonas putida***

A bacterium used for degrading harmful pesticides in contaminated agricultural soil.

Fungi (*Aspergillus niger*)

Used for phytoremediation of heavy metals like lead and cadmium from polluted farmlands.

Vetiver grass (*Chrysopogon zizanioides*)

Used for soil erosion control and phytoremediation of toxins in water bodies near agricultural fields.

Bioremediation**Oil spill cleanup (Hydrocarbon degradation)****Example**

The Deepwater Horizon Oil Spill (2010, Gulf of Mexico)

Bioprospected Organisms

Alcanivorax borkumensis, *Pseudomonas putida*, *Mycobacterium* spp.

Mechanism

These bacteria break down hydrocarbons (oil components) using specific enzymes such as alkane monooxygenase.

Application

During the Deepwater Horizon spill, scientists discovered that naturally occurring *Alcanivorax* populations increased in response to the oil contamination, contributing to the natural breakdown of petroleum.

Heavy metal removal from contaminated water**Example**

Gold Mine in Australia (Bioremediation of Mercury and Arsenic)

Bioprospected Organisms

Cupriavidus metallidurans, *Bacillus* spp.

Mechanism

Cupriavidus metallidurans can transform toxic heavy metals like mercury and arsenic into less harmful forms.

Bacillus species can bioaccumulate metals and immobilize them.

Application

In mining sites, these bacteria are used in bioreactors to remove toxic metals from wastewater before it is discharged.

Plastic degradation**Example**

PET Plastic Degradation by *Ideonella sakaiensis*

Bioprospected Organism

Ideonella sakaiensis, discovered in a Japanese waste site.

Mechanism

This bacterium produces PETase and MHETase enzymes that break down polyethylene terephthalate (PET) plastic into environmentally harmless monomers.

Application: Researchers are exploring ways to use *I. sakaiensis* or its enzymes in industrial waste treatment to help degrade plastic pollution.

Pesticide and Herbicide Degradation

Example: Atrazine Herbicide Biodegradation in Farmlands

Bioprospected Organisms

Pseudomonas spp., *Rhodococcus* spp.

Mechanism

Pseudomonas bacteria use enzymes to break down atrazine, a widely used herbicide, into non-toxic byproducts.



Rhodococcus species degrade other pesticides like lindane.

Application

These bacteria are used in bioaugmentation to decontaminate agricultural fields where pesticides have accumulated.

Personal care

Cosmetics

Antioxidants

Prevent skin aging and UV damage (e.g., resveratrol from grapes, astaxanthin from algae).

Hydrating agents

Natural moisturizers (e.g., hyaluronic acid from *Streptococcus* bacteria, aloe vera gel).

Natural pigments

Used in makeup and skincare (e.g., carotenoids from microalgae, anthocyanins from berries).

Anti-aging and anti-inflammatory compounds

Found in marine and botanical sources (e.g., fucoidan from brown seaweed, polyphenols from green tea).

Fortified food

Probiotics

Beneficial bacteria (e.g., *Lactobacillus*, *Bifidobacterium*) for gut health.

Prebiotics

Fibers that support gut microbiota (e.g., inulin from chicory root).

Omega-3 Fatty Acids

Essential for brain and heart health (e.g., sourced from microalgae like *Schizochytrium* and fish oil).

Plant-Based Proteins

Derived from legumes, algae, and fungi.

Natural Sweeteners and Fibers

Stevia rebaudiana (stevia) and resistant starch from bananas.

Approaches to biodiversity regulation Convention on Biological Diversity (CBD, 1992)

- Establishes sovereign rights over biological resources.

- Emphasizes Access and Benefit-Sharing (ABS) mechanisms.

Nagoya Protocol (2010)

- Provides guidelines for fair and equitable benefit-sharing from genetic resource utilization.
- Requires Prior Informed Consent (PIC) and Mutually Agreed Terms (MAT) for resource access.

World Trade Organization (WTO) – TRIPS Agreement

Includes provisions for protecting traditional knowledge through patents and intellectual property rights (IPR).

Scope of bioprospecting in India

India's vast biodiversity and deep traditional knowledge make it a prime region for bioprospecting in pharmaceuticals, agriculture, and biotechnology. With over 45,000 plant and 89,000 animal species, many of which are endemic, India is recognized as one of the world's 17 megadiverse countries. More than 400 ethnic groups and long-established medical systems such as Ayurveda, Siddha, Unani, and Tibetan medicine use around 7,500 plant species, and this ethnobotanical knowledge continues to guide modern drug discovery. To safeguard this heritage and prevent biopiracy, the Traditional Knowledge Digital Library (TKDL) documents traditional medicinal formulations and protects them from wrongful patenting. Economically, bioprospecting holds significant potential, with India's herbal medicine market projected to reach \$26.79 billion by 2030. It also promotes sustainable agriculture through biofertilizers, biopesticides, and plant growth-promoting microbes. In environmental management, bioprospecting supports bioremediation efforts. India's Biological Diversity Act (2002) ensures equitable benefit-sharing with indigenous communities.

Challenges

Biodiversity Loss



Deforestation, climate change, and habitat destruction threaten the availability of valuable biological resources.

Ethical and Legal Issues

Ensuring fair compensation for indigenous communities and source countries under international agreements like the Nagoya Protocol.

Sustainability Concerns

Overharvesting of bioresources can lead to ecological imbalance and species endangerment.

Biopiracy

Exploiting genetic resources without proper authorization or fair compensation can lead to conflicts and loss of benefits for local communities.

Future prospects

Drug discovery

Development of new antibiotics, cancer treatments, and neurological medicines.

Biotechnology and genetic engineering

Use of synthetic biology, CRISPR, and genomics to enhance bioactive compounds.

Sustainable agriculture

Innovation in biofertilizers, biopesticides, and drought-resistant crops.

Marine and extremophile research

Exploration of deep-sea organisms and marine-derived biomaterials for industrial and medical use.

AI and digital bioprospecting

Machine learning and big data to accelerate compound discovery.

Ethical and sustainable approaches

Strengthening fair benefit-sharing and eco-friendly resource management.

Conclusion

Bioprospecting is a transformative approach that bridges biodiversity conservation, scientific innovation, and sustainable development. By leveraging advancements in biotechnology, genomics, and AI, it unlocks novel bioactive compounds for medicine, agriculture, and industry, reinforcing the economic and ecological value of natural resources.

Ethical frameworks like Access and Benefit-Sharing (ABS) ensure fair compensation to indigenous communities while promoting conservation efforts. Sustainable bioprospecting not only protects biodiversity from overexploitation but also fosters eco-friendly industries and scientific breakthroughs. Moving forward, a balance between exploration, regulation, and conservation will be key to maximizing biodiversity's potential while safeguarding it for future generations.

References

- Afreen, S., & Abraham, B. P. (2008). Bioprospecting: promoting and regulating access to genetic resources and benefit sharing.
- Cao, S., & Kingston, D. G. (2009). Biodiversity conservation and drug discovery: Can they be combined? The Suriname and Madagascar experiences. *Pharmaceutical Biology*, 47(8), 809-823.
- Charlop-Powers, Z., Pregitzer, C. C., Lemetre, C., Ternei, M. A., Maniko, J., Hover, B. M., ... & Brady, S. F. (2016). Urban park soil microbiomes are a rich reservoir of natural product biosynthetic diversity. *Proceedings of the national academy of sciences*, 113(51), 14811-14816.
- Chien, A., Edgar, D. B., & Trela, J. M. (1976). Deoxyribonucleic acid polymerase from the extreme thermophile *Thermus aquaticus*. *Journal of bacteriology*, 127(3), 1550-1557.
- Cuevas, C., & Francesch, A. (2009). Development of Yondelis® (trabectedin, ET-743). A semisynthetic process solves the supply problem. *Natural product reports*, 26(3), 322-337.
- Miao, X. X., Xub, S. J., Li, M. H., Li, M. W., Huang, J. H., Dai, F. Y., ... & Huang, Y. P. (2005). Simple sequence repeat-based consensus



linkage map of *Bombyx mori*. *Proceedings of the National Academy of Sciences*, 102(45), 16303-16308.

Newman, D. J., & Cragg, G. M. (2020). Natural products as sources of new

drugs over the nearly four decades from 01/1981 to 09/2019. *Journal of natural products*, 83(3), 770-803.



Agroforestry and biodiversity conservation: Nurturing life above and below the ground

Babita Kumari¹ and Pooja Sharma²

¹Department of Silviculture and Agroforestry

²Department of Tree Improvement and Genetic Resources
College of Forestry, Dr. YS Parmar UHF, Nauni Solan (HP)

Email: babitabisha@gmail.com

Introduction

Biodiversity is fundamental to ecosystem stability and human well-being, yet it is declining rapidly due to land use change, habitat loss, overexploitation, pollution, invasive species and climate change. Global assessments by FAO and UNEP (FAO/UNEP, 2020) and IPBES warn that nature is being degraded at an unprecedented rate, threatening essential ecosystem services such as pollination, soil fertility, water regulation and climate regulation. In this context, agroforestry, which integrates trees with crops and or livestock, offers a practical approach to biodiversity conservation. By increasing landscape diversity and mimicking natural ecosystems, agroforestry systems provide habitats for plants, animals and soil organisms, support ecological connectivity and enhance ecosystem resilience, while also sustaining agricultural productivity and livelihoods (Jose, 2012).

Agroforestry as a tool for biodiversity conservation

Agroforestry is an effective tool for biodiversity conservation because it integrates trees and shrubs into agricultural landscapes, creating diverse habitats that support a wide range of plant, animal and soil organisms. These systems enhance species richness and genetic diversity by providing food, shelter and breeding sites, while diversified vegetation helps regulate pests and diseases through natural biological control (Altieri and Nicholls, 2004; Udawatta et al., 2021). By mimicking natural ecosystems, agroforestry improves landscape connectivity through features such as

hedgerows and riparian buffers, supports in situ conservation of native and traditional species and strengthens ecosystem resilience to climate change (Dawson et al., 2013). Agroforestry also conserves soil and water resources by reducing erosion, improving soil structure and fertility, enhancing water regulation and supporting below-ground biodiversity essential for nutrient cycling and ecosystem stability (Nair et al., 2010; Marsden et al., 2020).

Floral diversity in agroforestry system

Conventional agriculture largely relies on monocultures that prioritize food production but simplify ecosystems, leading to a sharp decline in floral diversity and reduced ecosystem resilience to pests, diseases and environmental stress (Varah et al., 2013; Mace et al., 2012). In contrast, agroforestry systems integrate trees, shrubs and crops, creating structurally complex and species-rich landscapes that support higher plant diversity and improved ecosystem functioning (Jose, 2012). This diversification enhances functional traits, stabilizes production systems and contributes to long-term sustainability.

Across regions, diverse agroforestry practices such as alley cropping, silvopasture, forest farming, riparian buffers and home gardens significantly enhance floral diversity. In North America, alley cropping and silvopastoral systems using species such as *Juglans*, *Populus* and *Quercus* increase plant richness and habitat heterogeneity (Garrett et al., 2009; Wolz and DeLucia, 2018). Tropical systems show similar trends, with home



gardens in South and Southeast Asia supporting exceptionally high species richness and functioning as reservoirs of native and useful plants (Kumar and Nair, 2006; Kabir and Webb, 2008). Studies from Sumatra and West Africa demonstrate that rubber and cocoabased agroforestry systems can approach the floristic diversity of secondary forests and far exceed that of monocultures (Murdiyarso et al., 2002; Asare, 2005). Global reviews confirm that agroforestry consistently maintains higher plant diversity than conventional agriculture and often bridges the gap between croplands and natural forests, underscoring its importance for floral biodiversity conservation (Tomich et al., 2001; Alkemade et al., 2009).

Faunal diversity in agroforestry system

Agroforestry systems support significantly higher faunal diversity than monocultures because their greater plant and structural complexity provides food, shelter and breeding habitats for a wide range of organisms, including pollinators, birds, insects and soil fauna (Jose, 2012). Pollinators are among the most important beneficiaries, as diversified tree-crop systems maintain flowering resources, nesting sites and favorable microclimates. While pollinator diversity declines sharply in monocultures, agroforestry systems retain a large proportion of forest pollinator species and functional roles, making them critical for both crop production and wild plant reproduction (Klein et al., 2003; Barrios et al., 2017). Mixed-tree systems are particularly effective in sustaining diverse and functionally important pollinator communities (Potts et al., 2010).

Agroforestry also enhances avian and insect diversity by increasing habitat heterogeneity and landscape connectivity. Shade-grown coffee and cocoa systems, windbreaks and riparian buffers have been shown to support higher bird richness than

adjacent monocultures and to act as corridors linking fragmented habitats (Harvey and Gonzalez-Villalobos, 2007). Increased insect diversity in these systems improves natural pest regulation, reducing crop damage and dependence on chemical inputs (Karp et al., 2013). Below ground, agroforestry promotes earthworms and other soil fauna through higher organic matter inputs and reduced disturbance, improving soil structure and nutrient cycling (Price and Gordon, 1999; Cardinael et al., 2018). Evidence from tropical regions further indicates that agroforestry can retain a large share of forest-associated fauna, including mammals and insects, underscoring its value as a biodiversity-friendly land use system in both temperate and tropical landscapes (Bhagwat et al., 2008).

Microbial biodiversity in agroforestry systems

Agroforestry systems support rich and functionally diverse microbial communities and offer a sustainable alternative to intensive, chemically driven agriculture that often degrades soil health and biodiversity (Araujo et al., 2012). By integrating trees with crops and or livestock, agroforestry enhances soil organic matter through continuous litter input, root turnover and reduced disturbance, which in turn increases microbial biomass and activity (Kaur et al., 2000). These systems conserve below and aboveground microbial diversity in the rhizosphere and phyllosphere, including nitrogen-fixing bacteria, mycorrhizal fungi and endophytes that regulate nutrient cycling, improve soil structure and strengthen ecosystem resilience (Radhakrishnan and Varadharajan, 2016). Agroforestry promotes diverse microbial functional groups such as rhizobia, actinorhizal Frankia, cyanobacteria, plant growth-promoting rhizobacteria and arbuscular and ectomycorrhizal fungi, which collectively enhance biological



nitrogen fixation, phosphorus uptake and plant stress tolerance (Nygren et al., 2012; Kumar and Adholeya, 2016). Tree species composition, system design and management strongly influence microbial community structure, with mixed-species and organically managed agroforestry systems consistently supporting higher microbial diversity than monocultures (Mungai et al., 2005; Bainard et al., 2011). These microbial interactions improve soil aggregation, water retention and nutrient availability, thereby underpinning the productivity, stability and longterm sustainability of agroforestry systems and reinforcing their role in biodiversity conservation and climateresilient land use (Zomer et al., 2009; Cardinael et al., 2018).

Illustrative examples and global applications of agroforestry

Across climatic regions, agroforestry demonstrates strong potential to conserve biodiversity while sustaining livelihoods. In the tropics, shade-grown coffee systems in Central and South America support diverse bird and insect communities by maintaining favorable microclimates and structural complexity (Buechley et al., 2015), while India's Kerala home gardens conserve high plant genetic diversity through multilayered tree crop arrangements that also enhance soil fertility and natural pest regulation. In Africa's Sahel, *Faidherbiaalbida* parklands improve soil nutrients and crop yields due to seasonal leaf shedding and nitrogen fixation (Sileshi et al., 2020). In temperate regions, alley cropping, silvopasture and forest farming are widely practiced, such as black walnut based intercropping in the United States and oak dominated dehesa systems in Spain and Portugal, which support livestock production and rich habitats. Policy driven initiatives further strengthen adoption, including Costa Rica's Payment for Ecosystem Services program, Kenya's

Green Belt Movement (Maathai, 2003), agroforestry innovations in the Brazilian Amazon and European Union support under the Common Agricultural Policy, collectively highlighting agroforestry as a globally adaptable strategy for biodiversity conservation and sustainable land use (Malezieux, 2012; Place et al., 2016).

Challenges and limitations

Despite its proven ecological benefits, agroforestry faces several constraints that limit widespread adoption. High initial establishment costs and delayed economic returns discourage smallholder and resourcepoor farmers, particularly in the absence of subsidies, credit access or incentives. Insecure land tenure further reduces willingness to invest in longterm tree based systems, as unclear property rights undermine future benefits (Garity, 2012). Cultural resistance, social norms and limited trust in extension services also slow adoption, especially where monocropping traditions dominate (Sanou et al., 2019). Policy gaps and weak institutional coordination between agriculture and forestry sectors create regulatory uncertainty, while the lack of dedicated agroforestry policies restricts technical and financial support (Rahman, 2017). Additionally, agroforestry requires specialized knowledge for managing complex tree crop livestock interactions, yet extension and training systems remain inadequate (Bonaudo et al., 2014). Climate variability, degraded soils and increasing pest and disease pressures further complicate system performance, demanding site specific research and integrated management approaches (Castle et al., 2022).

Future directions in agroforestry and biodiversity research

Future agroforestry research increasingly emphasizes climatesmart and biodiversityoriented approaches that enhance resilience, productivity and ecosystem services under climate change.



Climate smart agroforestry focuses on drought tolerant species selection, optimized tree-crop-livestock combinations and efficient water management to improve adaptation while supporting carbon sequestration and mitigation goals (Dinesh, 2016). At the same time, precision agroforestry using tools such as remote sensing, GIS and dronebased monitoring enables sitespecific management of soil, vegetation health and resource use efficiency. Biodiversityfocused models, including multistrata systems are gaining importance for ecological restoration of degraded landscapes and for supporting species richness, soil fertility and microclimate regulation (Sahoo et al., 2020). Scaling these benefits requires stronger policy integration; secure land tenure, financial incentives and well-coordinated research and extension systems aligned with global frameworks such as the SDGs and the Paris Agreement (Reid, 2017). Research priorities include developing locally adapted tree species, generating long-term ecological and socio-economic evidence, and exploring emerging opportunities such as carbon markets and digital agroforestry platforms (Stewart et al., 2022). Ultimately, effective multistakeholder collaboration among farmers, extension agencies, policymakers, private sector actors and international organizations will be central to advancing agroforestry as a key strategy for biodiversity conservation and sustainable development (Shiferaw et al., 2011).

Conclusion

Agroforestry represents a robust and sustainable approach to biodiversity conservation and land management by integrating trees with crops and livestock to enhance habitat diversity, genetic resources, species richness and essential ecosystem services such as soil fertility improvement, water regulation, carbon sequestration and natural pest control.

Although adoption is constrained by financial limitations, insecure land tenure, policy gaps and technical knowledge deficits, these challenges can be addressed through targeted innovations, effective extension and training, and supportive, coherent policy frameworks. Emerging climatesmart and precision agroforestry practices, supported by continued research and technological investment, further strengthen system efficiency and scalability. Equally important is coordinated engagement among farmers, researchers, policymakers, NGOs and the private sector to ensure knowledge sharing and institutional support. In the face of climate change, land degradation and food insecurity, agroforestry offers a resilient alternative to conventional agriculture, contributing to sustainable livelihoods, food security and longterm ecological balance.

References

- Alkemade R, Van Oorschot M, Miles L, Nellemann C, Bakkenes M and Brink B. 2009. GLOBIO3: A framework to investigate options for reducing global terrestrial biodiversity loss. *Ecosystems* **12**:374-390.
- Altieri MA and Nicholls CI. 2004. Effects of agroforestry systems on the ecology and management of insect pest populations. *Ecological engineering for pest management: Advances in habitat manipulation for arthropods*. CSIRO, Collingwood 143-155pp.
- Araujo ASF, Leite LFC, Iwata BF, Lira MA, Xavier G and Figueiredo MVB. 2012. Microbiological process in agroforestry systems. A review. *Agronomy for Sustainable Development* **32**:215-226.
- Asare R. 2005. Cocoa Agroforests in West Africa: A Look at Activities on Preferred Trees in the Farming Systems; Forest



- &LandscapeWorking Papers No. 6-2005; Forest & Landscape Denmark (FLD): Hørsholm, Denmark, 2005.
- BarriosE, Valencia V, Jonsson M,BraumanA,Hairiah K, Mortimer PE and Okubo S. 2017 Contribution oftrees to the conservation of biodiversity and ecosystem services in agricultural landscapes.*International Journal of Biodiversity Science, Ecosystem Services & Management***14**:1-16.
- Bainard LD, Klironomos JNandGordenAM. 2011. Arbuscular mycorrhizal fungi in tree-based intercropping systems: a review of their abundance and diversity. *Pedobiologia***54**:57
- Bhagwat SA, Willis KJ,Briks HJB and Whittaker RJ. 2008. Agroforestry: A refuge for tropical biodiversity?*Trends Ecology Evolution***23**:261-267.
- Bonaudo T, Bendahan AB, Sabatier R, Ryschawy J, Bellon S, Leger FandTichit M. 2014. Agroecological principles for the redesign of integrated crop–livestock systems. *European Journal of Agronomy***57**:43-51.
- Buechley ER, ŞekerciogluCH, Atickem A, Gebremichael G, Ndungu JK, Mahamued BA, Lens L. 2015. Importance of Ethiopian shade coffee farms for forest bird conservation. *Biological Conservation***188**: 50-60.
- CardinaelR, Guenet B, ChevallierT,DuprazC,Cozzi TandChenu C. 2018. High organic inputs explainshallow and deep SOC storage in a long-term agroforestry system–combining experimental and modelingapproaches. *Biogeosciences***15**:297-317.
- Castle SE, Miller DC, Merten N, Ordonez PJ and Baylis K. 2022. Evidence for the impacts of agroforestry on ecosystem services and human well-being in high-income countries: A systematic map. *Environmental Evidence***11**:10.
- Dawson IK, Guariguata MR, Loo J, Weber JC, Lengkeek A, Bush DandJamnadass R. 2013. What is the relevance of smallholders’ agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review. *Biodiversity and Conservation***22**:301-324.
- Dinesh D. 2016. Agricultural practices and technologies to enhance food security, resilience and productivity in a sustainable manner: Messages to the SBSTA 44 agriculture workshops.
- FAO/UNEP. 2020. The state of the world’s forests 2020.forests, biodiversity and people. Rome. <https://doi.org/10.4060/ca8642en>
- Garrett HE, McGraw RL and Walter WD. 2009. Alley Cropping Practices. In North American Agroforestry: An Integrated Scienceand Practice, 2nd ed.; Garrett, H.E., Ed.; American Society of Agronomy: Madison, WI, USA,pp. 133-162.
- Garrity D. 2012. Agroforestry and the future of global land use. Springer Netherlands21-27.
- HarveyCA and Gonzalez-Villalobos JA. 2007. Agroforestry systems conserve species-rich but modified assemblagesof tropical birds and bats. *Biodiversity Conservation***16**:2257-2292.
- Jose S. 2012. Agroforestry for conserving and enhancing biodiversity. *Agroforestry Systems***85**:1-8



- Kabir ME and Webb EL. 2008. Can home gardens conserve biodiversity in Bangladesh? *Biotropica* **40**:95-103.
- Karp DS, Mendenhall CD, Sandi RF, Chaumont N, Ehrlich PR, Hadly EA and Daily GC. 2013. Forest bolsters bird abundance, pest control and coffee yield. *Ecology Letters* **16**:1339-1347.
- Kaur B, Gupta SR and Singh G. 2000. Soil carbon, microbial activity and nitrogen availability in agroforestry systems on moderately alkaline soils in northern India. *Applied Soil Ecology* **15**:283-294.
- Klein AM, Steffan-Dewenter I and Tscharrntke T. 2006. Rain forest promotes trophic interactions and diversity of trap-nesting Hymenoptera in adjacent agroforestry. *Journal of Animal Ecology* **75**:315-323.
- Kumar BM and Nair PKR. 2006. Introduction, tropical home gardens: A time-tested example of sustainable agroforestry; Springer: Berlin/Heidelberg, Germany, pp. 1-12.
- Kumar S and Adholeya A. 2016. Impact of land use and soil types on arbuscular mycorrhizal fungal diversity in tropical soils of India. *African Journal of Microbiology Research* **10**:1595-1606.
- Mace GM, Norris K and Fitter AH. 2012. Biodiversity and ecosystem services: A multilayered relationship. *Trends in Ecology & Evolution* **27**:19-26.
- Marsden C, Martin-Chave A, Cortet J, Hedde M and Capowiez Y. 2020. How agroforestry systems influence soil fauna and their functions—a review. *Plant and Soil* **453**:29-44.
- Maathai W. 2003. The Green Belt Movement: Sharing the approach and the experience. Lantern Books.
- Malezieux E. 2012. Designing cropping systems from nature. *Agronomy for Sustainable Development* **32**:15-29.
- Mungai NW, Motavalli PP, Kremer RJ and Nelson KA. 2005. Spatial variation of soil enzyme activities and microbial functional diversity in temperate alley cropping systems. *Biology and Fertility of Soils* **42**:129-136.
- Murdiyarsod, Van Noordwijk M, Wasrin UM, Tomich TP and Gillison AN. 2002. Environmental benefits and sustainable land-use options in the Jambi transect, Sumatra, Indonesia. *Journal of Vegetation Science* **13**:429-438.
- Nair PR, Nair VD, Kumar BM and Showalter JM. 2010. Carbon sequestration in agroforestry systems. *Advances in Agronomy* **108**:237-307.
- Nygren P, Fernandez MP, Harmand J-M and Leblanc HA. 2012. Symbiotic dinitrogen fixation by trees: an underestimated resource in agroforestry systems? *Nutrient Cycling in Agroecosystems* **94**:123-160.
- Place F, Garrity D, Mohan S and Agostini P. 2016. Tree-based production Systems for Africa's Drylands. World Bank Publications.
- Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O and Kunin WE. 2010. Global pollinator declines: Trends, impacts and drivers. *Trends in Ecology & Evolution* **25**:345-353.
- Price GW and Gordon AM. 1999. Spatial and temporal distribution of earthworms in a temperate intercropping system in southern Ontario, Canada. *Agroforestry Systems* **44**:141-149.
- Radhakrishnan Sand Varadharajan M. 2016. Status of microbial diversity



- in agroforestry systems in Tamil Nadu, India. *Journal of Basic Microbiology* **56**:662–669
- Rahman SA. 2017. Incorporation of trees in smallholder land use systems: Farm characteristics, rates of return and policy issues influencing farmer adoption. Bangor University (United Kingdom).
- Reid R. 2017. Developing farmer and community capacity in Agroforestry: Is the Australian Master Tree Grower program transferable to other countries? *Agroforestry Systems* **91**:847-865.
- Sahoo SK, Lenka B, Raj A and Jhariya MK. 2021. Climate change impacts and mitigation through sustainable agroforestry practices. In *Advances in Sustainable Development and Management of Environmental and Natural Resources*. Apple Academic Press pp 1-265.
- Sanou L, Savadogo P, Ezebilo EE and Thiombiano A. 2019. Drivers of farmers' decisions to adopt agroforestry: Evidence from the Sudanian savanna zone, Burkina Faso. *Renewable Agriculture and Food Systems* **34**:116-133.
- Shiferaw B, Hellin J and Muricho G. 2011. Improving market access and agricultural productivity growth in Africa: What role for producer organizations and collective action institutions? *Food Security* **3**:475-489.
- Sileshi GW, Teketay D, Gebrekirstos A and Hadgu K. 2020. Sustainability of *Faidherbia albida*-based agroforestry in crop production and maintaining soil health. *Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges*. **2**:349-369.
- Stewart SB, O'Grady AP, Mendham DS, Smith GS and Smethurst PJ. 2022. Digital tools for quantifying the natural capital benefits of agroforestry: A review. *Land* **11**:1668.
- Tomich TP, Van Noordwijk M, Budidarsono S, Gillison A, Kusumanto T, Murdiyarso M, Stolle F and Fagi AM. 2001. Agricultural intensification, deforestation and the environment: Assessing tradeoffs in Sumatra, Indonesia. In *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*; Lee DR, Barrett CB, Eds.; CAB International: Wallingford, UK.
- Varah A, Jones H, Smith J and Potts SG. 2013. Enhanced biodiversity and pollination in UK agroforestry systems. *Journal of the Science of Food and Agriculture* **93**:2073-2075.
- Udawatta RP, Rankoth LM and Jose S. 2021. Agroforestry for biodiversity conservation. In: *Agroforestry and Ecosystem Services* pp 245-274.
- Wolz KJ and DeLucia EH. 2018. Alley cropping: global patterns of species composition and functions. *Agriculture Ecosystems and Environment* **252**:61-68.
- Zomer RJ, Trabucco A, Coe R and Place F. 2009. Trees on farm: analysis of global extent and geo-graphical patterns of agroforestry. ICRAF working paper # 89. World Agroforestry Centre, Nairobi, Kenya, pp 72



शहरी-वानिकी से पर्यावरणीय संतुलन: चुनौतियाँ एवं संभावनाएँ (विश्लेषणात्मक अध्ययन)

अनिमेष शुक्ला^{1*}, पूनम खेस¹, सिंधु खाखा² एवं पार्वती ताम्रकार³

¹वानिकी, वन्यजीव एवं पर्यावरण विज्ञान विभाग, गुरु घासीदास केंद्रीय विश्वविद्यालय, बिलासपुर, छत्तीसगढ़

²वनस्पति विज्ञान विभाग, नवीन शासकीय महाविद्यालय, धौरपुर सरगुजा, छत्तीसगढ़

³वानिकी विभाग, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर, छत्तीसगढ़

*Email: animeshshukla.forestry@gmail.com

प्रस्तावना:

बीसवीं व इक्कीसवीं सदी में आरंभ हुई शहरीकरण की प्रक्रिया, प्राकृतिक आवरण के ह्रास और जलवायु परिवर्तन की प्रमुख घटक बनी। वर्तमान वैश्विक परिदृश्य में भी तीव्र शहरीकरण ने प्राकृतिक संसाधनों पर अत्यधिक दबाव उत्पन्न किया है। शहरों का विस्तार, जनसंख्या वृद्धि, वाहन-प्रदूषण, उद्योगों की बढ़ती संख्या और हरित आवरण में निरंतर हो रही कमी ने पर्यावरणीय संतुलन को गंभीर रूप से प्रभावित किया है। आधुनिक शहर वैश्विक तापवृद्धि, वायु प्रदूषण, जैव-विविधता क्षरण, सामाजिक-स्वास्थ्य संकट एवं सतत् विकास से जुड़ी चुनौतियों के केंद्र बन चुके हैं (Tiwari *et al.*, 2022)। इसी संदर्भ में यह भी स्पष्ट होता है कि शहरीकरण की प्रबल व नितांत गति ने, न केवल भूमि-उपयोग प्रतिरूपों को बदला है, बल्कि पारिस्थितिक प्रक्रियाओं में भी बहुआयामी हस्तक्षेप किया है। प्राकृतिक आच्छादन के विनाश और पर्यावरणीय विकृति ने शहरी पारिस्थितिकीय तंत्र को अत्यंत संवेदनशील तथा असंतुलित बना दिया है।

इन गंभीर पर्यावरणीय असंतुलनों के प्रत्युत्तर में, शहरी-वानिकी (Urban Forestry) एक सशक्त, प्रभावी, व्यवहारिक एवं वैज्ञानिक समाधान के रूप में उभरी है। शहरी-वानिकी का आशय किसी महानगर, शहर या उपनगर की परिधि में, सड़कों, उद्यानों, संस्थानों, भवन प्रांगणों, आवासीय क्षेत्रों, उपवनों, अविकसित भू-भागों आदि में वृक्षारोपण, हरित संरचनाओं के निर्माण व संरक्षण, जैव-विविधता संवर्धन तथा पारिस्थितिक सेवा प्रदाय की सुव्यवस्थित प्रक्रिया से है (Miller *et al.*, 2015)। यह आयाम केवल वृक्षारोपण तक सीमित नहीं है, अपितु यह शहरी पारिस्थितिकी, मौसम विज्ञान, जैव-विविधता विज्ञान, कार्बन-द्रव्यमान बजटिंग, सामाजिक-पर्यावरणीय नियोजन एवं

भू-स्थानिक विश्लेषण (Geo-spatial Analysis) जैसे अनेक वैज्ञानिक पहलुओं को एकीकृत करने वाली बहु-विषयी अवधारणा है। शहरी-वानिकी पारिस्थितिक रूप से प्रेरित प्रबंधन रणनीति है जिसका उद्देश्य एक संतुलित, स्थायी एवं स्वास्थ्यवर्धक शहरी पर्यावरण का निर्माण करना है।

शहरी-वानिकी के वैज्ञानिक सिद्धांत एवं पारिस्थितिकीय लाभ:

शहरी-वानिकी को नगरीय हरित अवसंरचना (Urban Green Infrastructure) का एक अनिवार्य एवं आधारभूत घटक माना जाता है, जो विविध पारिस्थितिकी तंत्र सेवाओं (Ecosystem Services) के माध्यम से नगरीय पर्यावरणीय स्थिरता को सुदृढ़ करती है। वैज्ञानिक दृष्टिकोण से शहरी-वानिकी एक अंतःविषयक ढाँचा है, जिसमें जैविकी, पारिस्थितिकी, भू-विज्ञान, मौसम विज्ञान तथा सामाजिक विज्ञान के विविध आयाम समन्वित रूप से अंतर्निहित हैं (Vogt *et al.*, 2016)। इस परिप्रेक्ष्य में प्रत्येक शहरी वृक्ष को पृथक जैविक इकाई के रूप में नहीं, बल्कि एक व्यापक एवं जटिल शहरी पारिस्थितिक तंत्र-जाल के सक्रिय घटक के रूप में समझा जाता है, जो वायुमंडल, मृदा, जल-तंत्र, सूक्ष्मजीव समुदायों, कीट-पक्षियों तथा मानव समाज के साथ सतत् पारस्परिक अंतःक्रियाओं में संलग्न रहता है। नगरीय परिदृश्य में पर्यावरणीय संतुलन स्वाभाविक रूप से स्वतःस्फूर्त न होकर नियोजित मानवीय हस्तक्षेप, अवसंरचना विकास, प्रदूषण प्रबंधन तथा हरित नियोजन की समन्वित प्रक्रियाओं से निर्मित होता है (Konijnendijk *et al.*, 2005)। इस वैज्ञानिक संदर्भ में शहरी-वानिकी एक प्रभावी नियामक प्रणाली के रूप में कार्य करती है, जो वायुमंडलीय संघटन, ऊष्मीय व्यवस्था, जल-चक्र, मृदा स्वास्थ्य, जैव-विविधता



आदि को समेकित रूप से पुनर्संरचित कर अपेक्षाकृत स्थायी एवं संतुलित शहरी पर्यावरण की दिशा में प्रणाली को गतिशील बनाती है।

वायु गुणवत्ता एवं प्रदूषक अवशोषण

शहरी-वानिकी के अंतर्गत वृक्ष, वायु गुणवत्ता सुधार में एक प्रभावी जैविक तंत्र के रूप में कार्य करते हैं। पत्तियों की विस्तृत सतह संरचना (Leaf Surface Area Index) एवं रंध्रीय क्रियाशीलता (Stomatal Conductance) के माध्यम से वे सूक्ष्म कणीय पदार्थ (PM_{2.5}, PM₁₀) तथा नाइट्रोजन ऑक्साइड, सल्फर डाइऑक्साइड और ओजोन जैसे गैसीय प्रदूषकों को अवशोषित कर जैव-रासायनिक प्रक्रियाओं द्वारा निष्क्रिय करते हैं (Parsa *et al.*, 2019)। यह प्रक्रिया, जिसे जैवजनित वायु निस्पंदन प्रणाली (Biogenic Air Filtration System) कहा जाता है, वृक्ष प्रजाति, पर्ण-आकृति, जीवित द्रव्यमान तथा मौसमी परिस्थितियों पर निर्भर करती है। वैज्ञानिक अध्ययनों से यह प्रमाणित हुआ है कि घने वृक्ष आवरण विशेषकर सड़कों और शहरी परिवहन गलियारों के समीप, वायु प्रदूषण स्तर को उल्लेखनीय रूप से कम करने में सक्षम होते हैं। इस प्रकार, शहरी वृक्ष नगरीय परिवेश में जैविक वायु शोधकों के रूप में कार्य करते हुए वायु-शुद्धिकरण एवं पर्यावरणीय स्वास्थ्य संरक्षण में महत्वपूर्ण योगदान प्रदान करते हैं।

ताप-द्वीप प्रभाव (Urban Heat Island Effect) में कमी

शहरी क्षेत्रों में कंक्रीट, डामर एवं धात्विक संरचनाओं द्वारा ऊष्मा के अत्यधिक अवशोषण एवं रात्रिकालीन विकिरण के कारण उत्पन्न ताप-द्वीप प्रभाव एक प्रमुख नगरीय जलवायु समस्या है। वृक्षों तथा हरित क्षेत्रों का क्षय, शहरी ऊष्मा-द्वीप प्रभाव को तीव्र करता है, जिससे स्थानीय तापमान में वृद्धि होती है और ऊर्जा-आधारित शीतलन प्रणालियों पर निर्भरता बढ़ती जाती है। शहरी-वानिकी इस प्रभाव को कम करने में वैज्ञानिक रूप से प्रभावी भूमिका निभाती है, जहाँ वृक्षों की छत्रछाया (Canopy Cover), जलवाष्पोत्सर्जन (Evapotranspiration) तथा सतही ऊष्मा-परावर्तन गुणों के माध्यम से

परिवेशीय तापमान का नियमन होता है। वृक्ष पत्तियों द्वारा जल के वाष्पीकरण हेतु आवश्यक गुप्त ऊष्मा (Latent Heat) का उपयोग कर वातावरण से ऊष्मा अवशोषित करते हैं, जिससे स्थानीय तापमान में गिरावट आती है (Feng *et al.*, 2025)। वृक्षों का सघन वितान सूर्य के प्रत्यक्ष विकिरण को पक्की सतहों तक पहुँचने से रोकता है, परिणामस्वरूप सतह तापमान एवं ऊष्मा विकिरण में कमी आती है। विशेषतः बड़े वितान वाले पर्णपाती वृक्ष ग्रीष्म ऋतु में छायांकन तथा शीत ऋतु में सौर विकिरण की उपलब्धता सुनिश्चित कर शहरी ऊर्जा दक्षता और सूक्ष्म-जलवायु संतुलन को सुदृढ़ करते हैं, जिससे नगरीय परिवेश अपेक्षाकृत शीतल, आरामदायक एवं पर्यावरणीय रूप से संतुलित बनता है।

कार्बन अवशोषण एवं जलवायु नियंत्रण

वृक्ष प्रकाश संश्लेषण की जैव-रासायनिक प्रक्रिया के माध्यम से वायुमंडलीय कार्बन डाइऑक्साइड को अवशोषित कर उसे लकड़ी, पत्तियों तथा मृदा में जैव-द्रव्य के रूप में संग्रहीत करते हैं। इस प्रकार वृक्ष दीर्घकालिक कार्बन-भंडारण की भूमिका निभाते हुए नगरीय क्षेत्रों में प्रभावी शहरी कार्बन अवशोषण (Urban Carbon Sink) का निर्माण करते हैं (Bherwani *et al.*, 2024)। अध्ययनों से संकेत मिलता है कि शहरी वृक्ष प्रति वर्ष उल्लेखनीय मात्रा में कार्बन अवशोषित करने में सक्षम होते हैं, तथा परिपक्व वृक्षों में यह क्षमता और अधिक बढ़ जाती है। फलस्वरूप, शहरी-वानिकी वायुमंडलीय कार्बन सांद्रता को नियंत्रित कर जलवायु परिवर्तन के प्रतिकूल प्रभावों को कम करने में एक महत्वपूर्ण प्राकृतिक शमन तंत्र के रूप में कार्य करती है (Brandt *et al.*, 2016)।

जैव-विविधता संरक्षण

नगरीय परिदृश्य में शहरी-वानिकी, जैव-विविधता संरक्षण का एक सशक्त वैज्ञानिक माध्यम है, जो वृक्षों और हरित संरचनाओं के माध्यम से पक्षियों, तितलियों, परागणकर्ताओं तथा अन्य जीवों के लिए उपयुक्त आवास और संसाधन उपलब्ध कराती है। वृक्षों की शाखाएँ, छाल, कोटर और पर्ण-संरचना विभिन्न जीवों के लिए सूक्ष्म आवासों का निर्माण करती हैं, साथ ही



शहरी वनक्षेत्र, पारिस्थितिक संक्रमण क्षेत्रों (Ecotones) एवं जैविक गलियारों के रूप में कार्य करते हुए प्रजातियों के आवागमन और स्थायित्व को प्रोत्साहित करते हैं (Alvey, 2006)। विशेषतः स्वदेशी वृक्ष प्रजातियों का चयन स्तरीय वितान संरचना (Layered Canopy Structure) के विकास को सक्षम बनाता है, जिससे विविध पारिस्थितिक निकेतों का समर्थन होता है और देशी कीटों तथा उन पर निर्भर पक्षियों की उपस्थिति सुदृढ़ होती है। परिणामस्वरूप, नगरीय जैव-विविधता में वृद्धि पारिस्थितिक तंत्र की प्रत्यास्थता को बढ़ाती है, जिससे शहरी पारिस्थितिकी विभिन्न पर्यावरणीय आघातों के प्रति अधिक सहनशील, स्थिर और दीर्घकालिक रूप से संतुलित बनती है।

जल एवं मृदा: संवर्द्धन व संरक्षण

वृक्षों का वितान वर्षा जल को अवरुद्ध कर सतही अपवाह की तीव्रता और मात्रा को कम करता है, जिससे बाढ़ का जोखिम घटता है तथा जल को मृदा में अंतःस्रवण के लिए अधिक समय प्राप्त होता है, परिणामस्वरूप भू-जल पुनर्भरण को प्रोत्साहन मिलता है (Van *et al.*, 2018)। पर्ण-आवरण वर्षा-बूँदों की गतिज ऊर्जा को अवशोषित कर मृदा कटाव को सीमित करता है, जबकि वृक्षों की जड़ें मृदा संरचना को स्थिर रखकर अपरदन की प्रक्रियाओं को नियंत्रित करती हैं। साथ ही, पत्तियों एवं अन्य कार्बनिक अवशेषों के अपघटन से मृदा में कार्बनिक पदार्थ की वृद्धि होती है, जिससे उसकी सरंध्रता, जल-धारण क्षमता तथा जैविक सक्रियता में सुधार होता है (Ward *et al.*, 2021)। इस प्रकार शहरी-वानिकी, जल-प्रबंधन व मृदा-संरक्षण के समन्वित तंत्र हेतु एक प्रभावी प्रकृति-आधारित समाधान के रूप में कार्य करते हुए शहरी पर्यावरणीय स्थिरता को सुदृढ़ करती है।

सामाजिक-आर्थिक आयाम एवं मानव स्वास्थ्य

शहरी-वानिकी के सामाजिक-आर्थिक आयाम मानव स्वास्थ्य एवं शहरी कल्याण से गहराई से जुड़े हुए हैं। हरित खुले क्षेत्र मानसिक तनाव में कमी, शारीरिक गतिविधियों के संवर्द्धन तथा सामाजिक अंतःक्रिया व सामुदायिक सहभागिता

को प्रोत्साहित करते हैं, जिससे नागरिकों के समग्र स्वास्थ्य में सुधार होता है (Westphal, 2003)। वैश्विक स्वास्थ्य अध्ययनों द्वारा यह सत्यापित किया गया है कि हरित परिवेश शहरी जनसंख्या के मानसिक एवं शारीरिक स्वास्थ्य के लिए अनिवार्य है (Williams *et al.*, 2013)। पर्यावरणीय संतुलन के अतिरिक्त, शहरी-वानिकी ऊर्जा-दक्षता को बढ़ाकर भवनों में ऊर्जा खपत को कम करती है, जिससे दीर्घकालिक आर्थिक लाभ और कार्बन उत्सर्जन में कमी प्राप्त होती है। साथ ही, वृक्षारोपण, हरित अवसंरचना प्रबंधन तथा शहरी पारिस्थितिकी पर्यटन जैसे क्षेत्रों के माध्यम से यह स्थानीय रोजगार-सृजन को प्रोत्साहित कर सतत शहरी विकास को सामाजिक एवं आर्थिक दृष्टि से अधिक व्यवहार्य बनाती है।

शहरी-वानिकी की वर्तमान चुनौतियाँ

यद्यपि शहरी-वानिकी के पर्यावरणीय, सामाजिक और आर्थिक लाभ सुविदित हैं, तथापि इसके वैज्ञानिक एवं नीतिगत क्रियान्वयन में अनेक संरचनात्मक, तकनीकी व सामाजिक चुनौतियाँ विद्यमान हैं, जिन्हें संबोधित करना आवश्यक है। ये बाधाएँ भूमि-उपयोग नियोजन, शहरी विकास दबाव, संसाधन उपलब्धता तथा सामुदायिक सहभागिता जैसे विभिन्न स्तरों पर परिलक्षित होती हैं (Jim *et al.*, 2018)। इन चुनौतियों का प्रभावी समाधान तभी संभव है जब शहरी नियोजन, पारिस्थितिकी-आधारित प्रबंधन, नीति-निर्माण और जनसहभागिता को समन्वित एवं एकीकृत दृष्टिकोण के साथ लागू किया जाए।

भूमि का अभाव तथा अवसंरचनात्मक संघर्ष

शहरी क्षेत्रों में भूमि की सीमित उपलब्धता और तीव्र अवसंरचनात्मक विस्तार शहरी-वानिकी के प्रभावी क्रियान्वयन में प्रमुख बाधाएँ उत्पन्न करते हैं। भूमि-उपयोग परिवर्तन विश्लेषण से स्पष्ट है कि व्यावसायिक, आवासीय एवं औद्योगिक विस्तार के कारण हरित क्षेत्रों का निरंतर संकुचन हो रहा है। उच्च घनत्व वाले नगरीय परिवेश में पारगम्य मृदा की कमी, भूमिगत उपयोगिताओं तथा ऊपरी अवसंरचनाओं की उपस्थिति, वृक्षों की जड़-विकास, वितान-विस्तार, स्वास्थ्य एवं आयु को प्रतिकूल रूप से प्रभावित करती है (Carreiro,



2008)। साथ ही, रोपण स्थलों की अनुपयुक्तता अथवा प्रजाति चयन में त्रुटियाँ वृक्षों के निष्कासन का कारण बनती हैं, जिससे संसाधनों की क्षति होती है। परिणामतः, भूमि अभाव और अवसंरचनात्मक संघर्ष शहरी-वानिकी की स्थिरता के लिए एक गंभीर चुनौती के रूप में उभरते हैं।

अनुचित वृक्ष-प्रजातियों का चयन तथा मृदा गुणवत्ता की समस्याएँ

स्थानीय मृदा, जलवायु और पारिस्थितिकी की उपेक्षा कर विदेशी अथवा तीव्र-विकासशील प्रजातियों का रोपण शहरी-वानिकी में दीर्घकालिक पर्यावरणीय विकृतियों का एक प्रमुख कारण है। ऐसी प्रजातियाँ स्थानीय जैव विविधता, परागण तंत्र और मृदा-पोषक संरचना को बाधित करने के साथ जैविक आक्रमण एवं स्वास्थ्य संकटों को बढ़ावा देती हैं। वैज्ञानिक दृष्टि से प्रजाति-उपयुक्तता सूचकांक (Species Suitability Index) के आधार पर चयन आवश्यक है, विशेषतः तब, जब शहरी मृदा निर्माण गतिविधियों के कारण सघन, अल्प-वातित, कम जल-अंतःस्रवण वाली तथा रासायनिक संदूषकों या उच्च pH से प्रभावित होती है, जो जड़-विकास एवं पोषक अवशोषण को सीमित करती है। इसके अतिरिक्त, एकल-प्रजाति पर निर्भरता और दीर्घकालिक प्रबंधन की कमी शहरी वृक्षों के स्वास्थ्य, आयु और पारिस्थितिक लाभों को कम करती है (Nagendra *et al.*, 2011)। अतः जलवायु-लचीली तथा स्थानीय पारिस्थितिकी के अनुकूल प्रजातियों का वैज्ञानिक चयन शहरी-वानिकी की प्रभावशीलता के लिए अनिवार्य है।

संस्थागत प्रबंधन एवं वित्तीय समर्थन का अभाव शहरी-वानिकी की प्रभावशीलता रोपणोत्तर दीर्घकालिक प्रबंधन पर निर्भर करती है, जिसमें छँटाई, सिंचाई, रोग एवं कीट नियंत्रण तथा सतत निगरानी जैसी प्रक्रियाएँ सम्मिलित होती हैं (Mincey *et al.*, 2013)। किंतु अनेक नगर-निकायों में विशेषज्ञ मानव संसाधन, प्रशिक्षित वनकर्मियों तथा पर्याप्त वित्तीय आवंटन के अभाव के कारण यह प्रबंधन सुदृढ़ रूप से लागू नहीं हो पाता। परिणामस्वरूप शहरी वृक्षों का स्वास्थ्य

प्रभावित होता है और वे संरचनात्मक अस्थिरता के कारण सार्वजनिक सुरक्षा के लिए जोखिम उत्पन्न कर सकते हैं (Chaudhry *et al.*, 2011)। इसके अतिरिक्त, कई नगरों में समन्वित शहरी-वानिकी प्रबंधन योजना का अभाव तथा संस्थागत समन्वय की कमी शहरी-वानिकी के वैज्ञानिक एवं सतत क्रियान्वयन को और अधिक बाधित करती है।

सामाजिक व सामुदायिक सहभागिता की कमी शहरी-वानिकी पहलों की सफलता, सामुदायिक सहभागिता एवं स्थानीय स्तर पर स्वामित्व-बोध पर निर्भर करती है। नागरिकों में जागरूकता के अभाव तथा वृक्षों को सामूहिक संसाधन मात्र मानने की प्रवृत्ति के कारण संरक्षण व देखभाल के प्रयास कमजोर पड़ जाते हैं (Kuo, 2003)। शहरी-वानिकी के पर्यावरणीय एवं सामाजिक लाभों के प्रति अपर्याप्त समझ तथा नकारात्मक धारणाएँ जनभागीदारी को सीमित करती हैं, जिससे रोपण व संरक्षण कार्यक्रमों की प्रभावशीलता प्रभावित होती है।

शहरी-वानिकी की संभावनाएँ एवं तकनीकी नवाचार

आधुनिक वैज्ञानिक अनुसंधान, उन्नत प्रौद्योगिकी और सुदृढ़, दूरदर्शी नीतिगत ढाँचे के समन्वय से शहरी-वानिकी आज एक पारंपरिक पर्यावरणीय पहल से आगे बढ़कर भविष्य के नगरों के लिए प्रभावी प्रकृति-आधारित समाधान के रूप में स्थापित हो रही है (Esperon *et al.*, 2025)। वैश्विक स्तर पर विकसित वैज्ञानिक प्रतिमान, नवोन्मेषी तकनीकी अनुप्रयोग तथा भारत की विशिष्ट जैव-भौगोलिक विविधता का समुचित उपयोग शहरी-वानिकी की कार्यक्षमता, अनुकूलनशीलता और प्रभावशीलता को नई दिशा प्रदान कर रहा है। विद्यमान चुनौतियों के बावजूद, निरंतर वैज्ञानिक प्रगति व तकनीकी नवाचारों ने शहरी पारिस्थितिकी के सतत, लचीले और जलवायु-संवेदनशील विकास के लिए व्यापक व अभूतपूर्व संभावनाएँ सृजित की हैं।

हरित अवसंरचना का विकास

स्मार्ट-सिटी मिशन तथा अन्य राष्ट्रीय-राज्यीय पहलों के अंतर्गत हरित मार्गों, वायु-परिशोधन



वाटिकाएं एवं ऊर्ध्वाधर उद्यान जैसी संरचनाओं के माध्यम से सुसंगत शहरी हरित-तंत्र विकसित करने की व्यापक संभावनाएँ हैं। हरित गलियारे, जैव-नालिकाएँ, नगरीय उपवन तथा ऊर्ध्वाधर हरियाली जैसे वैज्ञानिक दृष्टि से सिद्ध प्रतिरूप जल-निकासी, प्रदूषण नियंत्रण व तापीय नियमन में प्रभावी योगदान देते हैं। शहरी-वानिकी को नगर नियोजन, भूमि-उपयोग, परिवहन और जल-प्रबंधन प्रणालियों के साथ एकीकृत कर, हरित पट्टियों, नदी-तट संरक्षण क्षेत्र व उद्यान-तंत्र के माध्यम से एक सुदृढ़ हरित अवसंरचना स्थापित की जा सकती है (Pearlmutter *et al.*, 2017)। भवन उपनियमों और विकास योजनाओं में न्यूनतम हरित क्षेत्र, वृक्ष-घनत्व तथा छत-बागवानी जैसी अवधारणाओं का समावेशन शहरी-वानिकी को सौंदर्यपरक तत्व से बढ़ाकर शहरी जीवन-समर्थन की मूलभूत अवसंरचना के रूप में स्थापित करने का दीर्घकालिक सिद्धांत बन सकता है।

तकनीक आधारित प्रबंधन

आधुनिक प्रौद्योगिकी के समावेशन से शहरी-वानिकी का प्रबंधन अधिक वैज्ञानिक, सटीक तथा प्रभावी बन रहा है। भू-स्थानिक सूचना प्रणाली (GIS), दूरसंवेदी तकनीक, ड्रोन-आधारित मानचित्रण तथा उच्च-विभेदन उपग्रह चित्रों के माध्यम से शहरी वृक्ष-आवरण, प्रजाति-विविधता, वितान घनत्व, कार्बन-संग्रहण क्षमता एवं ऊष्ण द्वीप प्रतिरूपों का विश्वसनीय आकलन संभव हुआ है। NDVI, पर्ण-क्षेत्र सूचकांक (LAI), LiDAR स्कैनिंग व शहरी ऊष्मा मानचित्रण जैसी वैज्ञानिक विधियाँ वृक्ष-स्वास्थ्य, आपदा मूल्यांकन एवं प्रबंधन प्राथमिकताओं के निर्धारण में महत्वपूर्ण भूमिका निभाती हैं (Staley, 2002)। इसके अतिरिक्त, इंटरनेट ऑफ थिंग्स (IoT) आधारित संवेदक मृदा-नमी, तापमान व पोषक-तत्वों से संबंधित वास्तविक-समय आधारित आँकड़े प्रदान कर सिंचाई एवं पोषण प्रबंधन को संसाधन-दक्ष बनाते हैं (Li *et al.*, 2017)। इन तकनीकों का एकीकृत उपयोग शहरी-वानिकी में साक्ष्य-आधारित नियोजन, लागत-कुशल प्रबंधन और दीर्घकालिक पर्यावरणीय लाभ सुनिश्चित

करने की दिशा में एक सशक्त वैज्ञानिक आधार बन सकता है।

स्वदेशी वृक्ष-प्रजातियों पर आधारित पारिस्थितिक पुनरुत्थान

स्वदेशी वृक्ष-प्रजातियाँ स्थानीय जलवायु, मृदा-गुणों, कीट-रोगों तथा परागण तंत्र के साथ सहविकसित होने के कारण शहरी पारिस्थितिकी में अधिक स्थिरता और अनुकूलनशीलता प्रदान करती हैं। इनका वैज्ञानिक रूप से नियोजित रोपण जैव-विविधता व परागणकर्ता समुदायों को सुदृढ़ करता है, साथ ही वृक्षों की आयु एवं पारिस्थितिक लाभों को भी बढ़ाता है। जैव-प्रौद्योगिकी और प्रजनन-विज्ञान में हुई प्रगति के माध्यम से स्थानीय पर्यावरणीय परिस्थितियों के अनुरूप अधिक सहनशील एवं पारिस्थितिक रूप से लाभकारी प्रजातियों का चयन व संवर्धन कर शहरी पारिस्थितिक पुनरुत्थान की मज़बूत नींव रखी जा सकती है (Tyrväinen *et al.*, 2005)।

नीतिगत सुधार एवं विधिक सुरक्षा

स्पष्ट एवं विज्ञान-सम्मत नीतियों तथा सुदृढ़ विधिक प्रावधानों के माध्यम से नगर निकायों, वन विभागों और शहरी विकास प्राधिकरणों द्वारा वृक्ष-कटान के प्रभावी नियंत्रण, हरित क्षेत्रों के संरक्षण तथा वृक्ष-स्वास्थ्य की नियमित निगरानी को सुदृढ़ किया जा सकता है (Nandi *et al.*, 2013)। शहरी नियोजन प्रक्रियाओं में हरित क्षेत्रों को अनिवार्य संरचनात्मक घटक के रूप में सम्मिलित कर शहरी-वानिकी के सतत् एवं प्रभावी क्रियान्वयन के लिए एक ठोस नीतिगत आधार प्रदान किया जा सकता है।

सामुदायिक सहभागिता एवं जन-जागरूकता

शहरी-वानिकी की दीर्घकालिक प्रभावशीलता स्थानीय समुदायों की सक्रिय सहभागिता, स्वामित्व-बोध और उत्तरदायित्व पर निर्भर करती है। शैक्षणिक संस्थानों, आवासीय संघों एवं सामाजिक संगठनों को वृक्षारोपण, संरक्षण व प्रबंधन से जोड़कर शहरी-वानिकी को एक व्यापक सामाजिक आंदोलन का स्वरूप दिया जा सकता है (Sievert, 1988)। जन-जागरूकता के माध्यम से शहरी वृक्षों को वायु-शुद्धिकरण, कार्बन-भंडारण, जैव-विविधता संरक्षण, ताप-नियमन एवं मानव-



स्वास्थ्य संवर्धन के वैज्ञानिक घटकों के रूप में स्थापित करना आवश्यक है। ऐसी वैज्ञानिक समझ विकसित होने पर नागरिक अपने व्यवहार तथा सामूहिक पहलों के माध्यम से शहरी पर्यावरणीय संतुलन के संरक्षण में सक्रिय एवं सतत् योगदान दे सकते हैं।

निष्कर्ष

शहरीकरण की गति ने न केवल प्राकृतिक परिसंपत्तियों के स्थानिक वितरण को परिवर्तित किया है, बल्कि पारिस्थितिक तंत्रों की वहन-क्षमता पर भी अभूतपूर्व दबाव डाला है। तीव्र अवसंरचनागत विकास, निर्माण गतिविधियों की बढ़ोत्तरी, भूमि-उपयोग शैली में निरंतर परिवर्तन तथा प्रकृति-आधारित सेवाओं की कमी ने शहरों को पर्यावरणीय असंतुलन की सीमा-रेखा पर ला खड़ा किया है। साथ ही, नगरीय अंचल में हरित क्षेत्र, वृक्ष-आवरण, प्राकृतिक संसाधनों के अनियंत्रित दोहन एवं पारिस्थितिक गलियारों के क्षरण ने शहरी निवासियों के जीवन-स्तर, स्वास्थ्य, मानसिक सुख-शांति तथा जल-वायु गुणवत्ता पर दीर्घकालिक प्रभाव डाला है। आज की शहरी परिस्थितियाँ इस आवश्यकता को रेखांकित करती हैं कि शहरों के विकास को केवल आर्थिक व अवसंरचनागत प्रगति के रूप में न देखा जाए, बल्कि पारिस्थितिक स्थिरता, पर्यावरणीय संतुलन, सामाजिक न्याय और प्रकृति-आधारित समाधानों के समन्वित ढाँचे में समझा जाए।

इन्हीं जटिल चुनौतियों के संदर्भ में शहरी-वानिकी का महत्व अत्यधिक बढ़ जाता है क्योंकि यह नगरीय पारिस्थितिकीय संतुलन को बनाए रखने के आधारबिंदु प्रदान करने के साथ-साथ जलवायु परिवर्तन शमन, जैव-विविधता संरक्षण, कार्बन अवशोषण, सूक्ष्म-जलवायु विनियमन, बाढ़-नियंत्रण, ध्वनि एवं वायु प्रदूषण में कमी तथा मानव स्वास्थ्य संवर्धन में भी एक प्रभावी और वैज्ञानिक समाधान प्रस्तुत करती है। यह पर्यावरणीय संतुलन स्थापित करने की दिशा में अपरिहार्य एवं वैज्ञानिक रूप से मान्य रणनीति है। शहरी-वानिकी, हरित अवसंरचना, पारिस्थितिक पुनर्स्थापन तथा सतत् भूमि-उपयोग जैसी अवधारणाएँ आज की पर्यावरणीय

चुनौतियों से निपटने के लिए अत्यंत आवश्यक उपकरण बनकर उभर रही हैं, जो भविष्य में मानव-समाज एवं प्रकृति के सह-अस्तित्व को सुनिश्चित कर सकती हैं। ऐसे परिवर्तित परिदृश्य में शहरी-वानिकी न केवल हरित आवरण को पुनर्स्थापित करने का माध्यम बनती है, अपितु यह शहरी पारिस्थितिकी तंत्र को वैज्ञानिक रूप से पुनर्गठित कर उसे पर्यावरणीय व्यवधानों के प्रति अधिक सहनशील व अनुकूलनशील बनाने की दिशा में भी महत्वपूर्ण योगदान देती है। अतः नगरीय नियोजन की मुख्यधारा में शहरी-वानिकी को समाहित कर ही शहरों को मानव-कल्याणोन्मुख, स्वस्थ, प्रत्यास्थ एवं पर्यावरणीय रूप से संतुलित बनाया जा सकता है।

संदर्भ

- Alvey, A. A. (2006). Promoting and preserving biodiversity in the urban forest. *Urban forestry & urban greening*, 5(4), 195-201.
- Bherwani, H., Banerji, T., & Menon, R. (2024). Role and value of urban forests in carbon sequestration: review and assessment in Indian context. *Environment, Development and Sustainability*, 26(1), 603-626.
- Brandt, L., Lewis, A. D., Fahey, R., Scott, L., Darling, L., & Swanston, C. (2016). A framework for adapting urban forests to climate change. *Environmental Science & Policy*, 66, 393-402.
- Carreiro, M. M. (2008). Introduction: the growth of cities and urban forestry. In *Ecology, planning, and management of urban forests: International perspectives* (pp. 3-9). New York, NY: Springer New York.
- Chaudhry, P., & Tewari, V. P. (2011). Urban forestry in India: development and research scenario. *Interdisciplinary Environmental Review*, 12(1), 80-93.



- Esperon-Rodriguez, M., Gallagher, R., Calfapietra, C., Cariñanos, P., Dobbs, C., Eleuterio, A. A., ... & Tjoelker, M. G. (2025). Barriers and opportunities for resilient and sustainable urban forests. *Nature cities*, 2(4), 290-298.
- Feng, R., Wang, F., Liu, S., Qi, W., Zhengchen, R., & Wang, D. (2025). Synergistic effects of urban forest on urban heat island-air pollution-carbon stock in mega-urban agglomeration. *Urban Forestry & Urban Greening*, 103, 128590.
- Jim, C. Y., Konijnendijk van den Bosch, C., & Chen, W. Y. (2018). Acute challenges and solutions for urban forestry in compact and densifying cities. *Journal of Urban Planning and Development*, 144(3), 04018025.
- Konijnendijk, C., & Randrup, T. B. (2005). Urban forestry education. In *Urban Forests and Trees: A Reference Book* (pp. 465-478). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Kuo, F. E. (2003). Social aspects of urban forestry: The role of arboriculture in a healthy social ecology. *Journal of Arboriculture* 29 (3): 148-155, 29(3).
- Li, X., Chen, W. Y., Sanesi, G., & Laforteza, R. (2019). Remote sensing in urban forestry: recent applications and future directions. *Remote Sensing*, 11(10), 1144.
- Miller, R. W., Hauer, R. J., & Werner, L. P. (2015). *Urban forestry: planning and managing urban greenspaces*. Waveland press.
- Mincey, S. K., Hutten, M., Fischer, B. C., Evans, T. P., Stewart, S. I., & Vogt, J. M. (2013). Structuring institutional analysis for urban ecosystems: A key to sustainable urban forest management. *Urban ecosystems*, 16(3), 553-571.
- Nagendra, H., & Gopal, D. (2011). Tree diversity, distribution, history and change in urban parks: studies in Bangalore, India. *Urban Ecosystems*, 14(2), 211-223.
- Nandi, S., & Gamkhar, S. (2013). Urban challenges in India: A review of recent policy measures. *Habitat International*, 39, 55-61.
- Parsa, V. A., Salehi, E., Yavari, A. R., & van Bodegom, P. M. (2019). Analyzing temporal changes in urban forest structure and the effect on air quality improvement. *Sustainable Cities and Society*, 48, 101548.
- Pearlmutter, D., Calfapietra, C., Samson, R., O'Brien, L., KrajterOstoic, S., Sanesi, G., & Alonso de Amo, R. (2017). The urban forest. *Cultivating green infrastructure for people and the environment* (Vol. 7, pp. 1-351). Springer.
- Sievert Jr, R. C. (1988). Public awareness and urban forestry in Ohio. *Arboriculture & Urban Forestry (AUF)*, 14(2), 48-51.
- Staley, D. C. (2022). Modern urban forestry for modern cities: Technology challenges and opportunities for the remote sensing of urban forests. *Arboriculture & Urban Forestry (AUF)*, 48(2), 147-163.
- Tiwari, G.; Shukla, A. and Anthony, F.M. 2022. Air pollution level declines the bird species diversity in an urban area: a case study of Bilaspur, Chhattisgarh during the summer season.



- International Journal of Agricultural and Applied Sciences, 3(2):29-34.
- Tyrväinen, L., Pauleit, S., Seeland, K., & De Vries, S. (2005). Benefits and uses of urban forests and trees. In *Urban forests and trees: A reference book* (pp. 81-114). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Van Stan II, J. T., Underwood, S. J., & Friesen, J. (2018). Urban Forestry: An underutilized tool in water management. In *Advances in chemical pollution, environmental management and protection* (Vol. 3, pp. 35-61). Elsevier.
- Vogt, J., Fischer, B. C., & Hauer, R. J. (2016). Urban forestry and arboriculture as interdisciplinary environmental science: importance and incorporation of other disciplines. *Journal of Environmental Studies and Sciences*, 6(2), 371-386.
- Ward, E. B., Doroski, D. A., Felson, A. J., Hallett, R. A., Oldfield, E. E., Kuebbing, S. E., & Bradford, M. A. (2021). Positive long-term impacts of restoration on soils in an experimental urban forest. *Ecological Applications*, 31(5), e02336.
- Westphal, L. M. (2003). Social aspects of urban forestry: Urban greening and social benefits: A study of empowerment outcomes. *Journal of Arboriculture* 29 (3): 137-147, 29(3).
- Williams, K., O'Brien, L., & Stewart, A. (2013). Urban health and urban forestry: How can forest management agencies help? *Arboricultural Journal: The International Journal of Urban Forestry*, 35(3), 119-133.



उत्तर प्रदेश के जनपद बुलंदशहर में एडनसोनिया डिजिताटा (*Adansonia digitata* Linn) के पेड़ पर एंथेसिस के समय पर सर्वेक्षण

यशवंत राय

वनस्पति विभाग, आई. पी. पी. जी. कॉलेज, बुलंदशहर, उत्तर प्रदेश

Email Id: - yrbotany@gmail.com

परिचय

एडनसोनिया डिजिताटा जिसे बाओबाब भी कहा जाता है। यह एक यूनिफेड पेड़ है। जैवविविधता बोर्ड उत्तर प्रदेश के द्वारा उत्तर प्रदेश में झूसी प्रयागराज, किन्तुर बाराबंकी, सुल्तानपुर, हमीरपुर आदि स्थानों पर एडंसोनिया एडंसोनिया डिजिताटा प्रतीक के कारण इन स्थानों को धरोहर घोषित किया गया है। यह अफ्रीका का मूल निवासी है उत्तर प्रदेश ही नहीं मध्य प्रदेश, राजस्थान व गुजरात में इस वृक्ष की पूजा की जाती है। यह मेडागास्कर का राष्ट्रीय वृक्ष है। भारत के मध्य प्रदेश राज्य में इसकी सबसे अधिक संख्या है। इसका वानस्पतिक नाम एडनसोनिया डिजिताटा (*Adansonia digitata* Linn.) जो मालवेसी कुल से संबंध रखता है। इसको बाओबाब का पेड़, उल्टा पेड़, खुरासानी इमली, व कल्पवृक्ष के नाम से भी जाना जाता है। इस पेड़ की बाह्य संरचना व फूल मनमोहक करने वाले होते हैं। यह भारत में संकटग्रस्त प्रजाति है। 24 नवंबर 2012 को किन्तुर, बाराबंकी में एडंसोनिया को देखा। इस पेड़ पर फूल फल नहीं थे। स्थानीय लोगों ने बताया कि इस पेड़ पर फूल अगस्त माह में आते हैं। 16 अगस्त 2013 को एडनसोनिया डिजिताटा के फूल देखने के लिये मेरठ से बाराबंकी गया। सोनी का कैमरा मेरे साथ था। दो फूल मुझे दिखाई दिये जिन पर मधुमक्खी मंडरा रही थी। बाराबंकी में इस वृक्ष को पारिजात के नाम से जानते हैं इस वृक्ष की पूजा की जाती है। कुछ स्थानीय लोग अपने शुभ कार्यों की शुरुआत इस वृक्ष के नीचे करते हैं। 2017 में आई पी कॉलेज बुलंदशहर में लगभग 25 वर्षीय, एडनसोनिया डिजिताटा पेड़ देखा। इस पर फूल फल नहीं थे 2024 तक फूल नहीं थे।

सर्वेक्षण साइट्स व रिजल्ट्स

एडनसोनिया डिजिताटा पर फूल खिलने के एकचुअल समय को रिकॉर्ड करने के लिये हमने आई पी पी जी कॉलेज, व नुमाइश ग्राउंड, बुलंदशहर उत्तर प्रदेश स्थलों को सर्वेक्षण के लिये चुना। आई पी कॉलेज में लगभग 35 वर्ष आयु व नुमाइश ग्राउंड में लगभग 17 वर्ष आयु के एडंसोनिया पर वर्ष 2025 में प्रथम बार लेखक ने खिलते फूल रिकॉर्ड किये। जुलाई 2025 के प्रथम सप्ताह में सैंकड़ों हरे रंग की छोटी गेंद के साइज की कली वृक्ष से नीचे की और लटकी हुई थी। 4 फूल भी खिले थे। मुझे प्रश्नता हुए की जिस पेड़ के फूल देखने 2012 व 2013 में मेरठ से बाराबंकी गया। आज ये फूल मुझे उस कॉलेज में देखने को मिल रहे हैं। जहाँ शिक्षक के रूप में कार्यरत हूँ। इसकी कलियाँ हरे रंग की मखमली सेपल्स लिये हुए होती हैं। एडंसोनिया की कली लगभग 6.8 सेमी लम्बी चौड़ाई 6.0 से 6.3 सेमी रिकॉर्ड किया जिसका वजन 70 ग्राम था। यह एक परिपक्व कली थी। फूल के डंठल कि लम्बाई 32.0 सेमी रिकॉर्ड की, फूल की लम्बाई 16.2 सेमी रिकॉर्ड की, फूल की चौड़ाई 19.1सेमी रिकॉर्ड की, स्टिमानल ट्यूब की लम्बाई 4.2 व स्टाइल के लम्बाई 10.2 सेमी रिकॉर्ड की एंथरस की संख्या 390 रिकॉर्ड की गई। यह इंटरस्टेड कार्य था। रात में फूल खिलने के समय सफेद पंखुड़ियाँ कैलिक्स के सिरे से बाहर निकलती हैं। फूलों में अच्छी खुशबू होती है। यह खुशबू रात्रि से दिन तक रहती है। परागण दोनों स्थानों पर परागण मधुमखियों के द्वारा होता रिकॉर्ड किया। कॉलेज में आते ही पहले एडनसोनिया डिजिताटा के फूलों की फोटोग्राफी करना कॉलेज से जाते हुए फोटोग्राफी करना एडनसोनिया डिजिताटा के फूल खिलने का एकचुअल समय इन्टरनेट गूगल साइट पर नहीं मिला, रिसर्च पेपर में भी कहीं एकचुअल समय मेशन नहीं था। जुलाई 2025 में इस पेड़ को देखने



के लिये ओरछा, मध्य प्रदेश गया। पेड़ के नीचे बैठने वाले बाबा से फूल के खिलने के समय के बारे में मालूम किया उन्होंने बताया प्रातः 04:00। पूर्ण रूप से क्लैक्स से पंखुड़ियों का बाहर आने का समय रात्रि 19:45 रिकॉर्ड किया। जुलाई, अगस्त, सितम्बर व अक्टूबर 2025 में इन दोनों अध्ययन स्थलों पर फूल खिलने का एकचुअल समय रात्रि 18:55 से 19:45 रिकॉर्ड किया गया। सारणी 1 को देखा जा सकता है। इस परिक्रिया को जुलाई, अगस्त, सितम्बर और अक्टूबर में लिये गये फोटोग्राफ में भी रिकॉर्ड किया है। जिसे आप फिग न से फिग न तक देख सकते हैं। सर्वेक्षण में निकॉन डी 5600 कैमरा, कैनन कैमरा व रियलमी मोबाइल का प्रयोग फोटोग्राफी में किया गया रात्रि 18:55 बजे से 19:30 तक कली का टिप से खुलने का स्थान धीरे धीरे बढ़ता है, लिपटी हुई पंखुड़ियों को धीरे धीरे बाहर आते रिकॉर्ड किया। यह मूवमेंट आप फिग Fig. no. 3 से 14 व Fig no.15 से 26, 27 व 28 व में देख सकते हैं। सर्वेक्षण में रात्रि समय 19:30 से 19:45 तक लगभग 15 मिनट में सफेद रंग के 5 पेटल्स, स्टाइल और स्टामिनल ट्यूब मूवमेंट के साथ 5 हरे रंग के सेपल्स से बाहर निकलते रिकॉर्ड किये। 15 मिनट का यह दृश्य वास्तव में मनमोहक था। 15 मिनट्स का सेपल्स के साथ पेटल्स का मूवमेंट ऊपर की ओर तेजी से होता रिकॉर्ड किया। जुलाई, अगस्त, सितम्बर और अक्टूबर में आई पी कॉलेज व नुमाइश ग्राउंड, बुलंदशहर उत्तर प्रदेश में चार महीनों में दोनों स्थानों पर लगभग रात्रि में 15 बार सर्वेक्षण किया। पूर्ण रूप से फूल खिलने का समय रात्रि 18:55 से 19:45 रिकॉर्ड किया गया। यदि तेज धूप है तो जो सेपल्स व पेटल्स रात्रि में मूवमेंट करके ऊपर गये थे वही अगले दिन 10:00 से 13:00 बजे तक सफेद रंग से ब्राउन रंग में

परिवर्तित होकर नीचे की ओर फैन जैसी सरंचना में लौट आते हुए ऑब्जर्व किये गये। Fig. no. 30. शाम तक या अगले दिन यह पूरी तरह फूल का सफेद रंग ब्राउन रंग Fig. no. 31 लेकर फूल नीचे गिर जाता है। लेकिन इन्ही माह में यदि दिनभर बारिश हो रही है। या दोपहर से बारिश हो रही है तो एडनसोनिया डिजिटटा पर फूल खिलने का दोनों स्थानों पर समय शाम 17:50 से 18:23, 18:27 व 17:50 से 18:30 रिकॉर्ड किया गया। सामान्य दिनों में एडसोनिया पर अन्थेसिस का समय 45 से 50 मिनट्स होता जबकि बारिश वाले दिन यह सामान्य दिन की अपेक्षा पहले व 30 से 40 मिनट्स का होता है। एडसोनिया पेड़ समय सूचक है यह भी सही हैं। David Baum and Tricia Handasyde (1990) ऑस्ट्रेलियाई बोआब के फूल दूसरे बोआब की तुलना में धीरे-धीरे खिलते हैं; फूल खिलने की प्रक्रिया लगभग 20 या 30 मिनट तक चलती है, जबकि *A. fony* में यह कुछ ही मिनटों में हो जाता है। Baum A.D.(1995) फूल सूखे या गीले मौसम में खिलते हैं; कलियाँ गोल होती हैं जिनका ऊपरी सिरा नुकीला शंकु जैसा होता है, ये अकेली होती हैं, कभी-कभी जोड़े में होती हैं; फूल का डंठल लटका हुआ होता है, 15 से 90 cm लंबा होता है। टेम्पोरल मार्कर बाओबाब फूल से जुड़े होते हैं। Goody (1993) टेम्पोरल मार्कर बाओबाब फूल से जुड़े होते हैं। एडनसोनिया डिजिटटा के फूल खिलने का एकचुअल समय आई पी पी जी कॉलेज व नुमाइश ग्राउंड बुलंदशहर जनपद उतर प्रदेश राज्य में रिकॉर्ड हुआ यह एकचुअल समय भारत के अन्य राज्यों को महत्वपूर्ण जानकारी देगा यदि समय से अंतर होता है ती नये शोध की एक दिशा मिलेगी।



सारणी - 1: एडनसोनिया डिजिताटा (*Adansonia digitata* L.) पर बारिस के दिन व सामान्य दिन में एंथेसिस का रिकॉर्ड किया गया वास्तविक समय

सर्वेक्षण साइट्स	सर्वेक्षण तिथि, माह व वर्ष	पंखुड़ियों का क्लैक्स से मूवमेंट कर बाहर आकर पंखे जैसी संरचना में आने का समय	पंखुड़ियों का कैलेक्स के साथ ऊपर की ओर मूवमेंट करने का समय
आई पी पी जी कॉलेज प्रथम कैम्पस बुलंदशहर	28 जुलाई 2025	18:55 -19:30	19:45
नुमाइश ग्राउंड, बुलंदशहर	29 जुलाई 2025	18:55 -19:30	19:45
नुमाइश ग्राउंड, बुलंदशहर	25 अगस्त 2025	18:55 -19:30	19:45
आई पी पी जी कॉलेज प्रथम कैम्पस बुलंदशहर	30 अगस्त 2025	18:55 -19:30	19:45
आई पी पी जी कॉलेज प्रथम कैम्पस बुलंदशहर	2 सितंबर 2025	18:55 -19:30	19:45
नुमाइश ग्राउंड, बुलंदशहर	29 सितंबर 2025	18:55 -19:30	19:45
नुमाइश ग्राउंड, बुलंदशहर	6 अक्टूबर 2025	18:55 -19:30	19:45
आई पी पी जी कॉलेज प्रथम कैम्पस बुलंदशहर	1 अक्टूबर 2025	18:55 -19:30	19:45
आई पी पी जी कॉलेज प्रथम कैम्पस बुलंदशहर	4 सितम्बर 2025(बारिस का दिन)	17:50	18:23, 18:27
नुमाइश ग्राउंड, बुलंदशहर	17 सितम्बर 2025(बारिस का दिन)	17:50	18:30





Fig. 1 a and b: Mature buds and flowers hanging from the branches of the *Adansonia digitata* tree in I. P.G. College, Bulandshahr. (Photo Dr. Yashwant Rai)

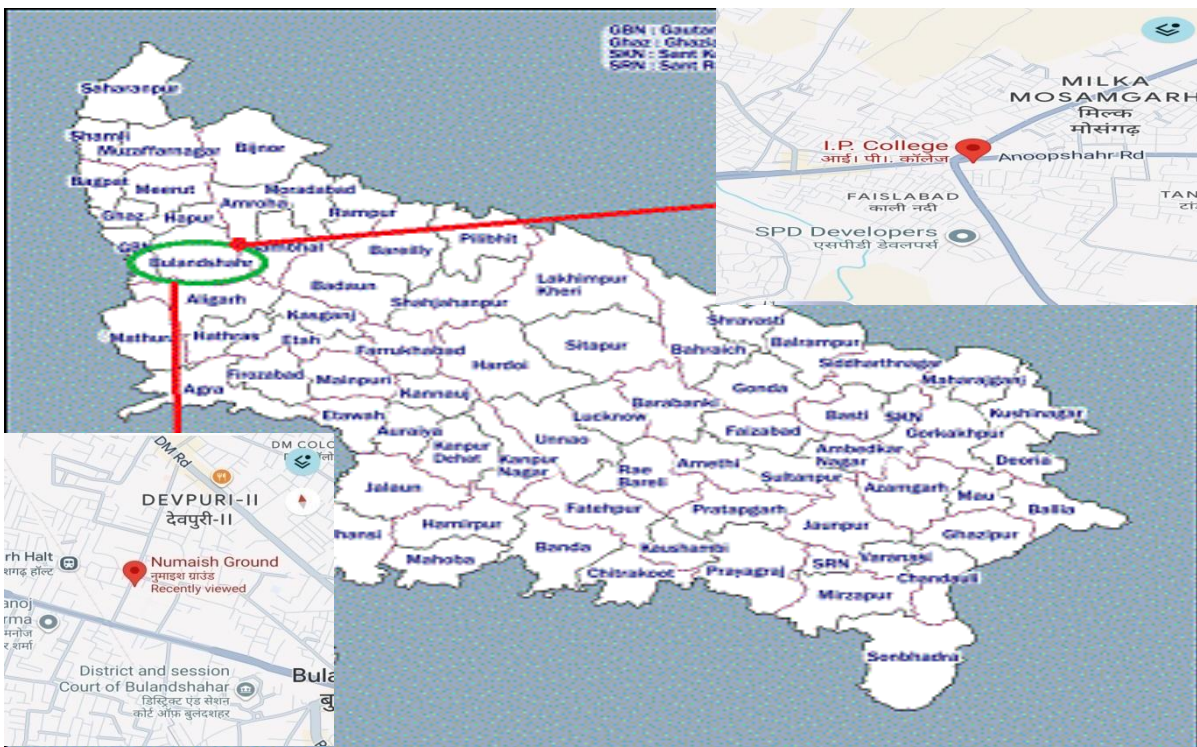


Fig. 2: Uttar Pradesh Map presenting location of 2 survey sites of *Adansonia digitata* Linn





Fig. 3 View mature bud (18:55)



Fig. 4. View of open tip



Fig. 5. View of open tip



Fig. 6. View of open tip



Fig. 7. View of open tip



Fig. 8. View of calyx (19:30)



Fig. 9. View of calyx (sepals)



Fig. 10. View of calyx and corolla



Fig. 11. View of calyx and corolla



Figure 12. View of calyx and corolla

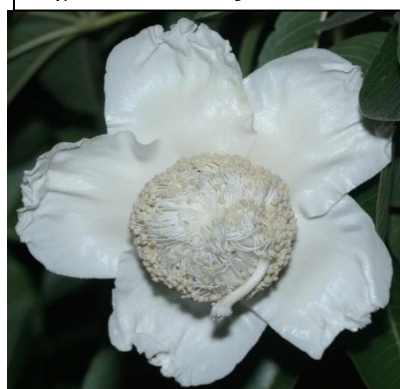


Figure 13. view of fan like structure of petals



Figure 14. view of upward movements of the petals (19:45)

All Photos taken by Dr. Yashwant Rai





Fig. 15. View mature bud (18:55)



Fig. 16. View of calyx movements



Fig. 17. View of calyx movements



Fig. 18. View of calyx and corolla



Fig. 19. View of calyx and corolla



Fig. 20. View of calyx and corolla



Fig. 21. View of calyx and corolla



Fig. 22. View of calyx and corolla



Fig. 23. View of calyx and corolla



Figure 24. View of fan like of calyx



Figure 25. view of upward movements of the petals



Figure 26. view of upward movements of the petals (19:45)

All Photos taken by Dr. Yashwant Rai





Figure 27 View of *Adansonia digitata* L. a and b flower 1 with pollinators Honey bees in I. P. College P. G. College Bulandshahr. Anthesis Time 18:16 to 18:23 (Rain day) Photo. Dr. Yashwant Rai



Figure 28. View of a and b *Adansonia digitata* flower 2 with pollinators Honey bees in I. P. College P. G. College Bulandshahr. Anthesis Time 18:21 to 18:27 (Rain day) Photo Dr. Yashwant Rai





Figure 29. View of structure of *Adansonia digitata* L flower. Photo Dr. Yashwant Rai



Figure 30. View of *Adansonia digitata* L flower in noon. Photo Dr. Yashwant Rai



Figure 31. View of *Adansonia digitata* L. dry flower Photo Dr. Yashwant Rai



References

Baum D. and Handasyde T. (1990) The Boab tree (*Adansonia gregorii*) in North- West Australia. Department of conservation &land management Western Australia.10491 pp1 -15

Baum A.D.(1995) systematic revision of *Adansonia* (bombacaceae) Missouri Bot. Vol. 82, no. 3, 440 - 470.

Goody, J. 1993. *The Culture of Flowers*. University Press,Cambridge, U.K.



सर्दी-खांसी से कैंसर तक: कुलंजन के चमत्कारी फायदे

अंकुर ज्योति शैकीया

वन संवर्धन एवं वन प्रबंधन प्रभाग

भा.वा.अ.शि.प. - वर्षा वन अनुसंधान संस्थान, जोरहाट, असम (भारत)

ईमेल: saikiaaj@icfre.org

क्या है कुलंजन की खासियत?

अदरक और हल्दी तो हर भारतीय घर की पहचान हैं, लेकिन क्या आप इनके 'चचेरे भाई' कुलंजन (Galangal) के बारे में जानते हैं? दक्षिण भारतीय व्यंजनों में 'चित्तरत्ता' और उत्तर भारत में 'कुलंजन' के नाम से मशहूर यह जड़ केवल एक मसाला नहीं, बल्कि आधुनिक विज्ञान की नजर में एक 'सुपरफूड' है। हालिया शोध यह बताते हैं कि यह पौधा औषधीय गुणों का पावरहाउस है। दिखने में यह अदरक जैसा लगता है, लेकिन इसका स्वाद थोड़ा तीखा और खुशबू चीड़ जैसी होती है। वैज्ञानिकों ने पाया है कि इसमें गैलंगिन (Galangin) नाम का एक खास तत्व होता है, जो शरीर में एंटीऑक्सीडेंट की तरह काम करता है।

अध्ययनों के अनुसार इसके प्रमुख लाभ हैं :-

फेफड़ों के लिए वरदान

भारतीय पारंपरिक चिकित्सा में इसका उपयोग फेफड़ों की सूजन और बलगम को ठीक करने के लिए किया जाता है। यह सांस की नली को साफ करने में मदद करता है।

पाचन में सहायक

यह पेट की गैस को दूर करता है और पाचन तंत्र को मजबूती देता है।

दर्द निवारक

इसमें जोड़ों के दर्द और सूजन को कम करने के गुण होता हैं।

कुलंजन का रासायनिक ढांचा

अगर हम इसकी पौष्टिकता पर नजर डालें, तो इसमें शरीर के लिए जरूरी खनिज जैसे सोडियम,

पोटैशियम और मैग्नीशियम प्रचुर मात्रा में पाए जाते हैं।

तालिका 1: कुंजन (*Alpinia officinarum*) का पोषण विश्लेषण (प्रति 100 ग्राम)

पोषक तत्व	मात्रा (लगभग)
नमी (Moisture)	10.5%
राख (Ash content)	4.8%
कच्चा फाइबर (Crude Fiber)	14.2%
कार्बोहाइड्रेट	70.3%
प्रोटीन	4.2%
ऊर्जा (Energy)	335.5 Kcal

क्या यह कैंसर से लड़ सकता है?

शोध पत्रों में सबसे चौंकाने वाली बात यह सामने आई है कि कुलंजन के अर्क में कैंसर कोशिकाओं (विशेषकर स्तन और फेफड़ों के कैंसर) के विकास को रोकने की क्षमता देखी गई है। यह शरीर में खराब कोशिकाओं को खुद-ब-खुद खत्म करने की प्रक्रिया (Apoptosis) को सक्रिय करता है। इसके अलावा, यह E. coli जैसे हानिकारक बैक्टीरिया से लड़ने में भी सक्षम है।

तालिका 2: मुख्य यौगिक और उनके फायदे

यौगिक (Compound)	मुख्य लाभ
गैलंगिन	एंटीऑक्सीडेंट, क्लूमर-रोधी
1, 8-सिनेओल	सांस की बीमारियों में राहत
क्वेरसेटिन	हृदय स्वास्थ्य और इम्युनिटी
केम्पेराइड	मस्तिष्क की कोशिकाओं की सुरक्षा



उपयोग कैसे करें?

सर्दी-खांसी के लिए

इसकी जड़ का एक छोटा टुकड़ा पानी में उबालकर चाय की तरह पिएं या इसे शहद के साथ मिलाकर लें।

गले की खराश

कुलंजन के टुकड़े को मुंह में रखकर चूसने से गले के संक्रमण में तुरंत आराम मिलता है।

भारतीय बाजारों में यह अक्सर सूखी जड़ के रूप में मिलता है। सावधानी: हालांकि यह प्राकृतिक

है, लेकिन इसका सीमित मात्रा में ही उपयोग करना चाहिए। गंभीर बीमारी की स्थिति में इसे दवा के विकल्प के बजाय पूरक के रूप में देखें और डॉक्टर की सलाह जरूर लें।

निष्कर्ष

कुलंजन हमारी प्राचीन विरासत का हिस्सा है। आधुनिक विज्ञान अब केवल उन दावों की पुष्टि कर रहा है जो हमारे आयुर्वेद में सदियों पहले लिखे गए थे। अपनी सेहत को बेहतर बनाने के लिए इस 'सुनहरी जड़' को फिर से अपनाने का समय आ गया है।





Published by:



Impact Factor

SJIF: 2022-6.071

ICFRE-Tropical Forest Research Institute
(Indian Council of Forestry Research & Education)
(An autonomous council under Ministry of Environment, Forests and Climate Change)
P.O. RFRC, Mandla Road
Jabalpur-482021, M.P. India
Phone: 91-761-2840484
Fax: 91-761-2840484
E-mail: vansangyan_tfri@icfre.gov.in, vansangyan@gmail.com
Visit us at: <http://tfri.icfre.org> or <http://tfri.icfre.gov.in>



©Published by ICFRE-Tropical Forest Research Institute, Jabalpur, MP, India