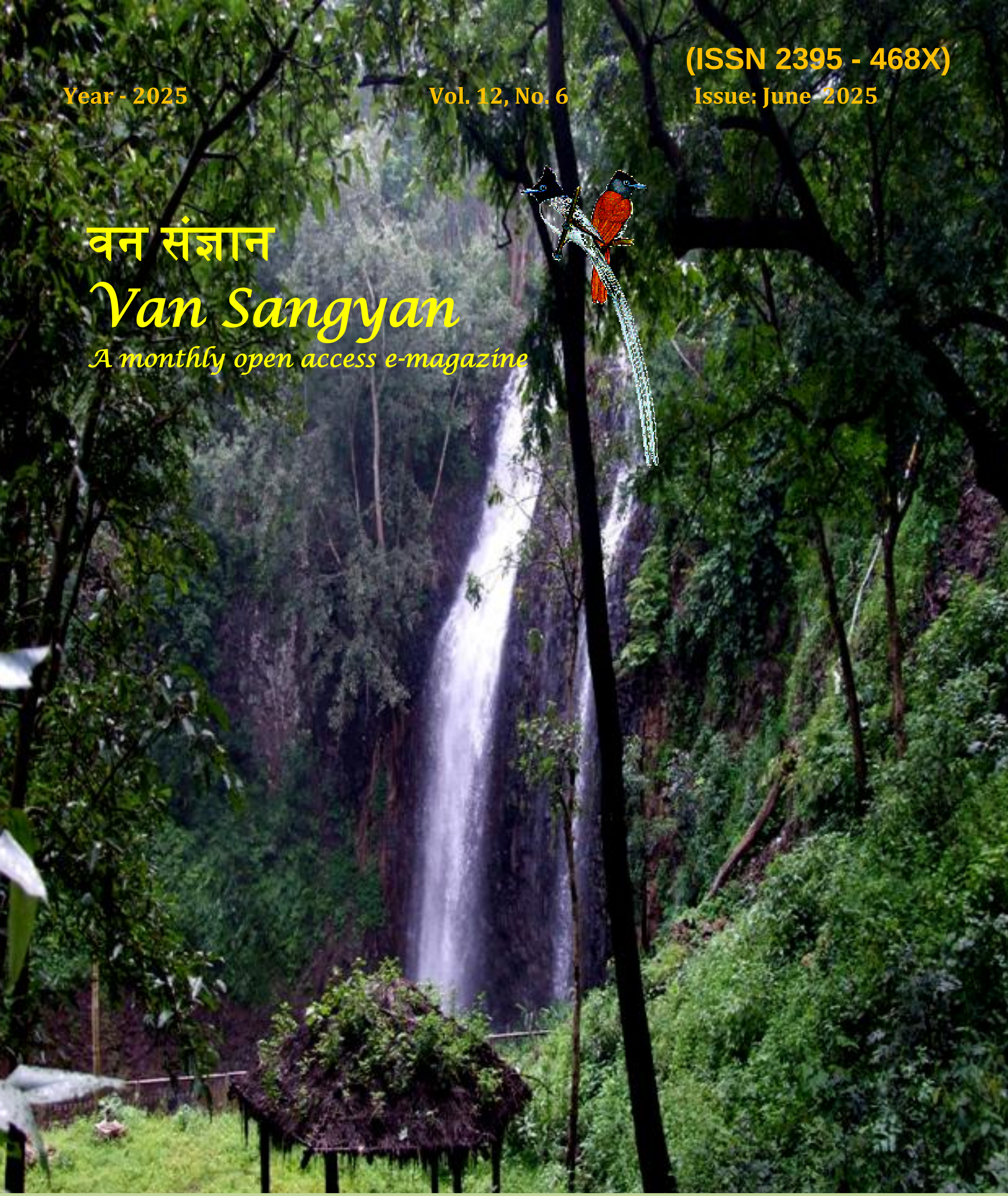
(ISSN 2395 - 468X)
Year - 2025 Vol. 12, No. 6 Issue: June 2025

वन संज्ञान
Van Sangyan
A monthly open access e-magazine



Indexed in:
COSMOS Foundation (Germany)
International Inst. of Org. Res. (Australia)
IIJIF

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

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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

As the world intensifies efforts to restore forests and combat climate change, forest nurseries play a critical role in growing healthy, resilient trees. Biofertilizers—natural soil enhancers made from beneficial microorganisms—are proving to be a game-changing solution for boosting seedling growth and survival. Unlike chemical fertilizers, biofertilizers improve nutrient absorption, stimulate root development, and increase resistance to stress, all while maintaining soil health and reducing environmental impact. They offer a cost-effective, eco-friendly alternative, especially beneficial for low-resource nurseries and community-based forestry projects. However, broader adoption faces challenges, including limited awareness and inconsistent performance across species. Continued research, policy support, and education are key to realizing their full potential. Biofertilizers represent a sustainable step forward—supporting not just trees, but the ecosystems and communities that depend on them.

In line with the above this issue of Van Sangyan contains an article on Enhancing tree growth in forest nurseries: The impact of biofertilizers. There are also useful articles viz. Growth performance of different tree species under industrial agroforestry systems in South Gujarat, Examining the importance of flagship species in conservation efforts, Agroforestry: A sustainable solution for land degradation neutrality, Agroforestry: A game changer for sustainable agriculture and climate resilience, Assessment of propagation techniques for Albizzia lebbeck, Coconut crop conquerors: A close look at invasive insect pests in India, Green credit programme, Hardwickia binata Roxb. - A resilient agroforestry tree for sustainable land use and An overview of vegetation in Kanha Tiger Reserve.

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Enhancing tree growth in forest nurseries: The impact of biofertilizers

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Introduction

Plants require balanced nutrition for optimal growth and yield. Biofertilizers are organic substances added to the soil to enhance fertility and promote plant growth. When applied to soil, biofertilizers offer several benefits, such as improving soil fertility, structure, and water retention, while increasing soil organic matter, which can help reduce the reliance on synthetic fertilizers for crop production (Blay *et al*., 2002).

The application of bio-fertilizers improves nutrient and water uptake, promotes plant growth, and enhances tolerance to both abiotic and biotic stressors. These biological fertilizers are crucial for producing quality seedlings, sustaining soil health, and protecting the environment, making them eco-friendly and cost-effective options for farmers (Malik Asif *et al*., 2018). Typically, tree growth is considered slow to moderate and often requires silvicultural treatments to enhance it. However, bio-fertilizers can effectively address the issue of slow seedling growth. Their use is advantageous because they are natural, biodegradable, organic, cost-effective, and contain beneficial bacterial cultures and nutrient solutions that support both plant and soil health.

Forest nurseries play a critical role in reforestation and afforestation efforts. The health and growth of seedlings are vital for successful planting, and biofertilizers have emerged as a promising solution to enhance tree growth in these settings.

What are Biofertilizers?

Biofertilizers are natural fertilizers that contain living microorganisms. These organisms promote plant growth by increasing the availability of nutrients, enhancing soil health, and improving root development. Common types of biofertilizers include:

- **Nitrogen-fixing bacteria** (e.g., Rhizobium, Azotobacter)
- **Mycorrhizal fungi** (e.g., Glomus species)
- **Phosphate-solubilizing bacteria** (e.g., Pseudomonas, Bacillus)

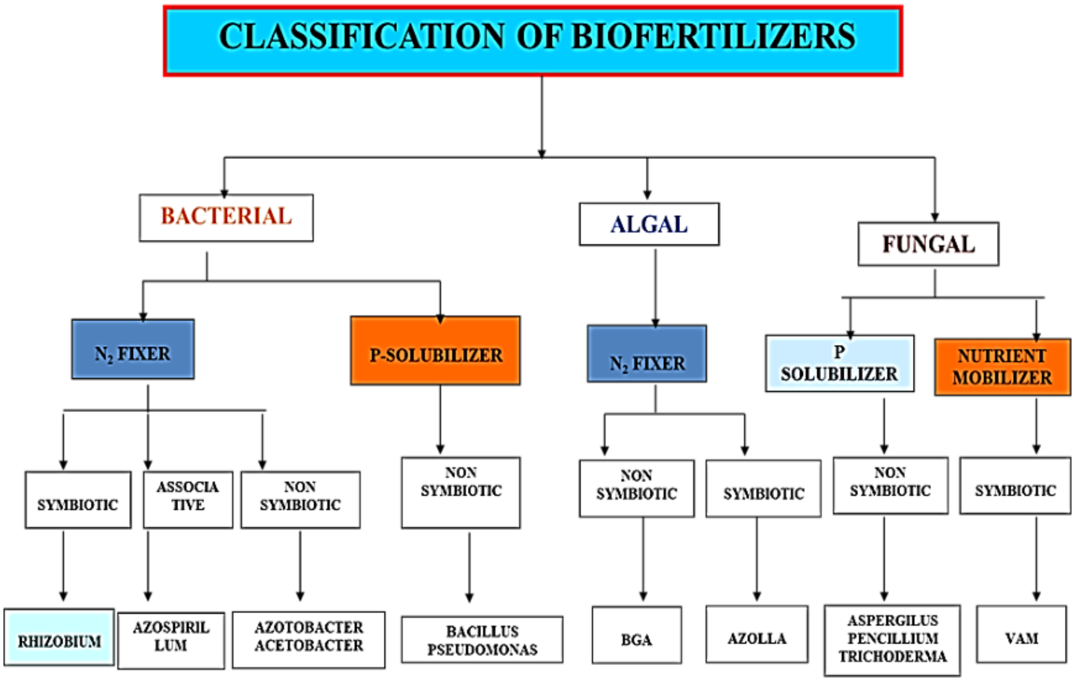

Fig. 3. Classification of biofertilizers.

Benefits of Bio-fertilizers

1. Biofertilizers are environmentally friendly and do not negatively impact soil fertility, health, plant growth, or the environment. As natural products containing living microorganisms, they can enhance crop yields by 3 to 39% and help maintain soil nitrogen levels, promoting sustainable farming practices.
2. Their formulations are cost-effective, and the application methods are straightforward, allowing poor, small, and marginal farmers to easily prepare and use biofertilizers such as Azolla, blue-green algae (BGA), and other organic materials based on their specific needs.
3. A wide range of biofertilizers is available, each with proven benefits for numerous crop species. These products are effective in smaller quantities, pollution-free, sourced from renewable energy, and offer a high cost-benefit ratio without risks, while also improving the efficiency of chemical fertilizers.
4. In addition to their immediate effects on crops, biofertilizers have a significant beneficial residual impact on soil fertility, promoting root growth and enhancing overall crop establishment.
5. They also improve crop nutrition, maintain soil fertility, and increase resilience to drought and moisture stress by producing growth-promoting substances, vitamins, and hormones. Furthermore, they help suppress weed growth, reduce pathogen incidence, and control diseases through the secretion of antibiotics, antibacterial, and antifungal compounds.

6. The inoculation of biofertilizers enhances microbial activity and population, increases the availability of secondary and micronutrients, and helps reduce environmental pollution by detoxifying heavy metals in the soil.
7. When used in conjunction with chemical fertilizers, organic manure, and crop residues, biofertilizers can significantly improve soil health and crop productivity, as well as nutrient use efficiency.

Role of Biofertilizers in Tree Growth

Nutrient Availability

Biofertilizers can enhance the availability of essential nutrients, particularly nitrogen and phosphorus, which are crucial for tree growth.

Improved Soil Structure

They can improve soil structure, leading to better water retention and aeration, which are vital for seedling health.

Root Development

Mycorrhizal fungi, in particular, form symbiotic relationships with plant roots, extending the root system and improving nutrient and water uptake.

Disease Resistance

Some biofertilizers can help seedlings develop resistance to pathogens, reducing the need for chemical fertilizers and pesticides.

Sustainability

Using biofertilizers supports sustainable forestry practices by reducing chemical inputs and promoting a healthier ecosystem.

Case Studies and Research Findings

Research has demonstrated the positive effects of biofertilizers on various tree species in nursery conditions:

Eucalyptus

Studies have shown that the application of mycorrhizal fungi can significantly enhance the growth rates of Eucalyptus seedlings compared to those grown with conventional fertilizers. Biofertilizers of organic substrates and rhizospheric bacteria stimulate growth, improve the morphological attributes of Eucalyptus grandis seedlings, and improve the chemical properties of the soil; these effects are related to the activity of potentially beneficial microbial consortia present in biofertilizers. The application of biofertilizers allows E. grandis seedlings to reach a height and primary root diameter suitable for final transplant, showing the effectiveness of inoculation with rhizobacteria. These mixtures of biofertilizers can be used in E. grandis production programs to increase productivity per hectare and significantly reduce the use of chemical fertilizers, reducing the negative impact on the environment (González-Díaz *et al.*, 2019) the seedling height, collar diameter, number of leaves, total seedling length, biomass production and Dickson's quality index were found significantly higher in T7 ((Azatobactor + Azospirillum + P-solubalizer (10 g +10 g + 10 g/seedling)) than that of control and T2 ((Azospirillum (10 g/seedling)). In general it has found that application of biofertilizers were strongly influenced the growth parameters (Chavan *et al.*, 2013).

Application Methods

Soil Incorporation

Biofertilizers can be mixed into the soil before planting to establish beneficial microbial populations.

Seed Treatment

Coating seeds with biofertilizers before planting can boost early growth and establishment.

Foliar Sprays

Some biofertilizers can be applied as foliar sprays, providing immediate nutrient benefits.

Challenges and Considerations

While biofertilizers offer numerous benefits, challenges include:

Variability in Effectiveness: The effectiveness of biofertilizers can vary based on soil type, environmental conditions, and tree species.

Integration with Other Practices

Successful use often requires integration with good nursery management practices, such as watering, mulching, and pest management.

Public Awareness

Educating nursery managers and foresters about the benefits and use of biofertilizers is crucial for widespread adoption.

Conclusion

Biofertilizers represent a sustainable and effective approach to enhance tree growth in forest nurseries. By improving nutrient availability, soil health, and seedling resilience, they can play a pivotal role in successful reforestation and afforestation initiatives. Continued research and practical applications in different forestry contexts will help maximize their benefits and contribute to healthier forests.

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Growth performance of different tree species under industrial agroforestry systems in South Gujarat

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Abstract
Fast growing tree species with multipurpose benefits such as plywood, pulpwood, timber and fuel wood. The species is suitable for plantation programme under various agro-climatic conditions. Thus, in the recent scenario the species has greater attraction by farmers, foresters and plantation growers. The growing demand for timber can be met to some extent by utilizing alternate species and increasing the timber production through intensive silviculture management. Hence, the plantations of fast growing, short rotation woody trees like *Casuarina equisetifolia, Melia dubia, Eucalyptus globulus, Leucaena leucocephala* gained more importance. The fundamental hypothesis of the present experiment is to estimate growth parameters like, Height, Girth and Crown spread of species at five years time intervals to find out performance of these four tree species. Maximum tree height found in *Eucalyptus globules* (13.84 m), Maximum tree girth found in *Leucaena leucocephala* (44.22 cm), Maximum tree Crown spread (E-W) found in *Eucalyptus globulus* and *Leucaena leucocephala* (1.97 m*)* while Maximum tree Crown spread (N-S) found in *Eucalyptus globulus* (1.96 m).

Keywords: Industrial, Agroforestry, Growth parameters, Tree species, Crown spread

The National Agroforestry Policy (2014) defines agroforestry as a combination of land-use systems which combines trees and shrubs on farmlands and rural landscapes with or without livestock to enhance productivity, profitability, diversity, and ecosystem sustainability (Singh *et al*. 2021). The agroforestry system was the major source of reducing the pressure on the forests by increasing the tree cover in the landscapes. Higher potential to increase environmentally and economically returns to the local society for major distribution in agriculture to get food, fodder, timber, fuelwood, and fiber for the developing socioe-conomically status (Bijalwan *et al*. 2011). Agroforestry has been practiced traditionally in India in the form of subsistence farming, but is being increasingly recognized from the economic point of view, in addition to its positive contribution to the wood-based industrial sector, which has recent origin. Low forest cover, poor productivity and legal restrictions coupled with an increasing demand for wood and wood products due to increasing population, industries and associated policy changes have ushered in a total mismatch between demand and supply. This has attracted increasing attention towards agroforestry. The National Forest Policy of India 1988 has directed all wood-based industries to generate their own raw material resources by linking farmers and extending technology and market support (Parthiban *et al*. 2021).

Agroforestry system is mainly predominant in the arid and semi-arid regions of the country and irregular forms of the native trees like Leauceana spp., Prosopis spp., Acacia spp., and Ficus spp. in the form of silvopasture system practiced by the local cultivators prominently in India (Viswanath *et al*. 2018). The tree requires deep red gravelly soil, high light intensity, rainfall of about 800-1000 mm and an elevation of 800-1000 mtrs. Seedlings can tolerate frost; however, severe frost can result in plant death. The farmers were encouraged to plant a *Melia dubia* with different agricultural crops in large scale just because of its industrial and ecological importance (Parthiban *et al.* 2009; Nuthan *et al.* 2009). The most commonly measured dimensions are height and diameter, because these are convenient measures that are strongly correlated with wood volume and biomass. Stem basal area (the cross-sectional area of stems sometimes expressed per unit ground surface area) can be calculated from diameter, and is also useful in ecological and physiological studies (Mencuccini *et al*. 2005).

Materials and methods

Study area

The experiment was conducted during 2023-24 at instructional farm, arboretum, College of Forestry, Navsari Agricultural University, Navsari, South Gujarat. Geographically it is located at 20.95° N latitude and 72.93° E longitude with an elevation of 11 m above mean sea level (AMSL). This area is typically characterized by humid and warm monsoon with rainfall of about 1500-1800 mm, moderately cold winter, and fairly hot and humid summer. The average annual temperature is 27.1 °C.

Methods

Five year old plantations were established with 3×2 m spacing to estimate the growth performance of different four tree species likely, *Casuarina equisetifolia*, *Melia dubia*, *Eucalyptus globulus*, *Leucaena leucocephala* were established under different four models. A total of 32 trees were planted for each species. The trees planted in the four blocks were 128 trees (Figure 1). This experiment was designed in a randomised block design with four treatments (different tree species) viz., T_1:- *Casuarina equisetifolia*, T_2:-*Melia dubia*, T_3:- *Eucalyptus globulus*, T_4:- *Leucaena leucocephala* and four replications. To find out the better growth performance of tree species viz., Tree height (m), Tree girth (cm), Tree crown spread (E-W) and Tree crown spread (N-S). The height of trees was measured by dendrometer, Trunk circumference at breast height (1.34 m) was measured using a measuring tape and the crown spread with the help of tape for each and every individual tree.

Statistical Analysis

Recorded five-year average data of variables were analysed and compared by analysis of variance (ANOVA) of randomised block design with the critical difference, C.V. and S.E.M. (Panse and Sukhatme 1995).

Results and discussion

Table 1: Growth performance of different tree species

Treatments	Tree Height (m)	Tree Girth (cm)	Crown spread (m) (E-W)	Crown spread (m) (N-S)
Casuarina equisetifolia L.	11.72	30.35	1.71	1.69
Melia dubia Cav.	10.63	36.22	1.38	1.36
Eucalyptus globulus Labill.	13.84	33.54	1.97	1.96
Leucaena leucocephala (Lam.) de Wit.	8.90	44.22	1.97	1.93
C.D. at 5 %	1.08	3.26	0.09	0.11
SE(m)	0.33	1.00	0.03	0.03
C.V. %	5.91	5.57	3.01	3.93

Tree height (m) and Tree girth (Girth at breast height, cm)

There was a significant variation in height and girth among studied tree species from 5 years of observation (Table 1). *Eucalyptus globulus* 13.84 m attained maximum height and *Leucaena leucocephala* shows 8.90 m minimum height. While *Leucaena leucocephala* 44.22 cm attained maximum girth and *Casuarina equisetifolia* 30.35 cm shows minimum girth. However, results indicate that the among established all four tree species *Eucalyptus* gained good height as compare to other and higher girth circumstances gained by *Leucaena leucocephala*.

Thakur *et al.* (2023) provided support for this finding, revealing significant variation in tree height and DBH growth, GJ09 (local family from Northern most tip of Western Ghats, parts falling in Gujarat) achieved significantly maximum height (11.20 and 13.33 m, respectively) and DBH (15.26 and 18.00 cm, respectively) compared other families. (Patil *et al*. 2017) provided support for this finding, revealing significant difference among different planting densities and maximum was recorded in planting density of 714 trees/ha (46.85 cm, 10.59 m; 50.14 cm, 10.99 m; 52.99 cm,11.22 m and 55.76 cm,11.43 m) for both girth (cm) and height (m), respectively for all the time interval. Tree height (*Acrocarpus fraxinifolius*) varied significantly and the maximum tree height was recorded in Mudigere and Chikamagaluru (26.14 m) populations. The difference in GBH was found to be non-significant across the populations, which could be due to selection of trees in particular girth class, as described by (Ashwath *et al.* 2020). (Dechamma *et al* 2020) reported that among the different clones except for tree height, Clone CH-10 showed substantially higher growth in terms of DBH (2.96 cm). However, tree height was found to be maximum in CH-2 (4.01m) which was on par with CH-10, CH-4 and CH-5. Further, consistent lower performance of the intraspecific hybrid (CJ-9) observed for the parameters such as height (3.39 m), DBH (2.23 cm), and volume (443.27 cm3). In Sindigere among all the clones, CH-4 showed better growth performance in terms of quantitative traits such as total height(4.64m), DBH (3.04 cm), CBH (0.81m) and volume (1159.22 cm3). Similarly, result was observed by (Dejenea *et al.* 2018) that Eucalyptus species showed good growing performances both in height and in DBH.

Tree crown spread (E-W) and crown spread (N-S)

There was a significant variation in crown spread (E-W) and crown spread (N-S) among studied tree species (Table 1). *Eucalyptus globules and Leucaena leucocephala* both 1.97 m attained maximum crown spread (E-W) and *Melia dubia* shows 1.38 m minimum crown spread (E-W). *Eucalyptus globules* 1.96 m attained maximum crown spread (N-S) which is statistically at par with *Leucaena leucocephala 1.93 m* and *Melia dubia* shows 1.36 m shows minimum crown spread (N-S). Similar result found by (Shambharkar *et al.* 2024) examining CSNS aspect variation between *P. marsupium* and *P. santalinus*, irrespective of their seed sources and locations, a substantial difference emerges. Specifically, *P. marsupium* exhibits a wider CSNS aspect (14.01 m), contrasting with the narrower CSNS aspect (9.79 m) observed in *P. santalinus*, which ranges from 7.80 m to 22.65 m and higher range 5.30 m to 24.00 m, respectively. Das et al. 2019 observed the maximum canopy spread was recorded in *A. procera* (timber tree) and *M. azedarach* (MPTs). The minimum canopy spread was recorded in *P. pinnata* followed by *Aegle marmelos*, and *A. indica* which suggested the suitability of these species to be planted at a closer spacing under different agroforestry systems. It is worth noting that both species have spreading branches, as described by Gopikumar *et al.* (2003) *P. marsupium* had a highly spreading crown, while *P. santalinus* was described as having stout, crooked stems with ranged widely spreading branches.

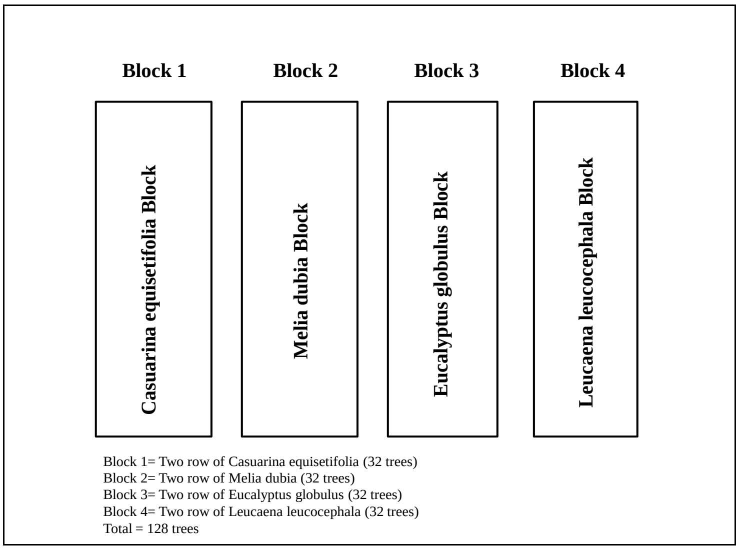

Figure 1: Layout of different tree species at experimental site, Navsari campus

Conclusion

Based on the above discussion, it can be concluded that the experiment demonstrated the variation in tree height, tree girth and crown spread (E-W) and (N-S) has been observed among four different tree species. Among all *Eucalyptus globulus* attained maximum height that's directly mean that the growth rate of *Eucalyptus globulus* was higher than among four species while *Leucaena leucocephala* attained maximum girth means higher peripheral growth gained by *Leucaena leucocephala*. In terms of canopy expansion *Eucalyptus globules and Leucaena leucocephala* attained maximum crown spread (E-W) as compare to other studied tree species.

Acknowledgement

The experiment was funded by the Government of Gujarat, India, through the Development of Industrial Agroforestry Models for South Gujarat Region plan project. We sincerely thank Navsari Agricultural University, Gujarat, India, for granting us access to the facilities needed to complete this experiment.

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Examining the importance of flagship species in conservation efforts

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Introduction

A flagship species is a species selected to act as an ambassador and are an important tool for mobilizing support for conservation. An ideal flagship species: (1) is endemic to one area but known far beyond that region; (2) has economic importance within the culture; (3) It can act as an umbrella species; and (4) has a declining population (Bowen-Jones & Entwistle, 2002; Caro & O'Doherty, 1999; Entwistle & Stephenson, 2000; Simberloff, 1998; Walpole & Leader-Williams, 2002). By focusing on, and achievingconservation of that species, the status of many other species which share its habitat or are vulnerable may also be improved. Communities facing economic hardships are particularly at risk from biodiversity loss, as their livelihoods often depend directly on natural sources of food and fuel. The continued destruction of biodiversity due to human activities results in the permanent loss of genetic resources, reducing the capacity for future evolutionary adaptation.Flagship species are an important conservation tool because they can be used to reach out to the general public and raise funds for conservation. (Bowen-Jones and Entwistle, 2002). The'In-situ' conservation of a flagship species will result in the conservation of a significant number of other species as well (Dietz and Nagagata, 1994). This concept can also be especially powerful and effective when applied at the level of individual organisms.Selection of particular individuals – what we term "flagship individuals" – as figure heads of conservation, marketing, advocacy, or education can not only generate empathy through communicative and psychological mechanisms but also serve as an embodiment or archetype to symbolize a cause (Wald *et al.*, 2021).

The concept and features of flagship individuals

Flagship individuals are selected members of a species or community chosen to represent broader conservation, cultural, or social causes. These individuals are typically charismatic or visually striking, making them effective symbols to raise awareness and garner support for important initiatives. As they typically belong to charismatic species, flagship individuals therefore exhibit the "charismatic traits" (example; beautiful, impressive, endangered) of their conspecifics (Albert *et al.* 2018; Courchamp *et al.* 2018). They play a pivotal role in conservation efforts by drawing attention to endangered or threatened species and acting as focal points for advocacy and fundraising. Often holding cultural significance, flagship individuals inspire collective action, serve as educational tools, and promote greater understanding of biodiversity and ecological issues. Their ability to symbolize a cause makes them powerful agents for change.

In India, several flagship individuals have become symbols of conservation and cultural importance. For example, the Bengal Tiger is a prominent flagship species, representing wildlife conservation efforts and symbolizing strength and beauty. Similarly, the Indian Elephant serves as a flagship for habitat conservation, particularly in areas where human-elephant conflict is prevalent. The One-Horned Rhinoceros in KazirangaNational Park is another flagship species, drawing global attention to the need for rhino conservation. These species not only represent India's rich biodiversity but also play key roles in educating the public and fostering conservation action.

The Role of Flagship Species inConservation intensions

Flagship species play a crucial role in conservation efforts worldwide. These are species selected to represent an environmental cause, ecosystem, or conservation initiative. By focusing on these species, conservationists can leverage public interest, funding, and policy changes to benefit broader ecological communities.

Flagship Species Capturing Public and Political Attention

Public Engagement and Awareness

Flagship species serve as icons that captivate public interest, increasing awareness and concern for environmental challenges. Their appeal sparks widespread support through social media, documentaries, and educational campaigns. By forming an emotional bond with these species, people are driven to take part ingrassroots movements and advocacy initiatives.

Fundraising and Policy Impact: Conservation initiatives centred on flagship species draw substantial financial support from governments, NGOs, and the public. Their widespread appeal makes them powerful catalysts for influencing conservation policies, as policymakers often react to public demand and global attention.

Global conservation Branding

Flagship species often appear in news, documentaries, and campaigns, keeping environmental issues in focus. Conservation groups use their images for branding, boosting awareness and support. A notable example WWF's panda logo, which has become one of the most recognizable symbols of conservation efforts worldwide. attracting donations, partnerships, and public involvement in conservation.

Benefits of Emphasizing Flagship Species

Poaching & Trafficking Crackdowns

- High-profile species often lead to tighter enforcement and surveillance against wildlife crime.
- Their visibility pushes governments and agencies to take action and monitor illegal trade routes more seriously.

Genetic Conservation Repositories

- Some flagship species (like rhinos or cheetahs) drive investments in cutting-edge genetic conservation, like cloning, cryopreservation, and advanced breeding.
- This helps develop future-ready conservation science.

Youth Empowerment & Education

- Kids often fall in love with animals like dolphins, tigers, or polar bears-turning them into young conservationists.
- Flagship species help fuel school programs, wildlife clubs, and youth activism in a super engaging way.

Tourism Diplomacy & International Relations

- Countries sometimes use flagship species as soft power tools—they help build partnerships between nations through shared conservation goals.
- Example: China's "panda diplomacy," where giant pandas are loaned to zoos around the world to foster good relations.

Cultural & Creative Inspiration

- Flagship species inspire art, music, films, books, and folklore—keeping conservation alive in hearts and minds.
- Example; animals like Tiger, Leopard, elephant play a major role in cultural aspects in India.

Challenges of Relying on Flagship Species

Neglect of Less "Charismatic" Species

- Focusing on big, cute, or majestic animals (like pandas or elephants) often means less attention-and funding-for lesser-known but equally important species (e.g. frogs, insects, plants, fungi).
- This can lead to imbalanced conservation efforts.

Uneven Funding priorities

- NGOs and governments may feel pressured to support "marketable" species to attract donations—even if other species are more at risk.
- It turns conservation into a kind of popularity contest.

Zoos and Captive Focus

- Some campaigns emphasize flagship species in captivity (like in zoos), which might distract from habitat conservation in the wild.
- It can give a false sense of security that the species is doing fine.

Conflict with Humans

- Some flagship species (e.g. tigers, wolves, elephants) come into conflict with local communities by preying on livestock or damaging crops.
- This can lead to resentment or backlash against conservation efforts.

Successful case story

Case study 1

- Conducting threat assessments and snare removal surveys by

HYTICOS: These are critical to identifying and mitigating poaching risks

to tigers and prey species in vulnerable habitats. These efforts combined with community involvement and advanced

monitoring techniques, aim to ensure safer ecosystems and promote long-term wildlife conservation.

Prey Monitoring

Case study 2:

The Status of Vultures in India:

A story of Decline and Recovery:

The populations of three vulture species-The White-Rumped Vulture(*Gyps bengalensis*), Indian Vulture (*Gyps indicus*), and Slender-Billed Vulture (*Gyps tenuirostris*)-had declined by more than 95%.

The primary cause of this sudden and alarming

, Assam, and Uttar Pradesh. The program involves working closely with local communities, veterinarians, and cattle owners to promote the use of vulture-safe alternatives to diclofenac, such as meloxicam, which does not harm vultures.

Current Status

While the initial population decline was catastrophic, there has been a glimmer of hope in recent years. Populations of the three critically endangered species-White-rumped, Indian, and Slender-billed vultures—are stabilizing in some regions. Breeding programs have seen success, and the creation of vulture-safe zones has helped reduce the risk posed by toxic carcasses.

Since 2010, running one of India's longest prey monitoring programmes at Kawal, Amrabad and Nagarjuna sagar Srisailam Tiger Reserves.

Tiger Monitoring

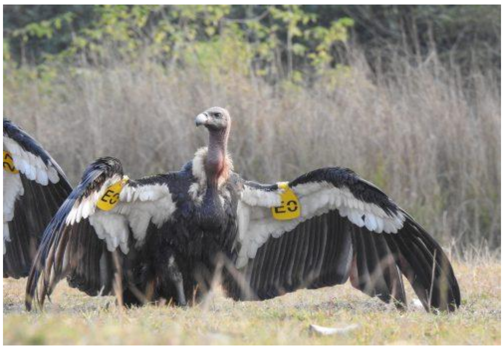
Since 2001, HyTiCoS has been assisting forest partments in annual counting operations.

decline was the widespread use of the veterinary drug diclofenac, an anti-inflammatory given to livestock. When vultures fed on the carcasses of animals treated with diclofenac, they suffered from acute kidney failure, leading to their rapid demise. The drug, which was introduced in the early 1990s, had devastating unintended consequences for vulture population.

Conservation Efforts: Vulture Safe Zone (VSZ) program

A program where diclofenac-free areas are established, ensuring safe environments for vultures to thrive. These zones have been set up in states like Madhya Pradesh

The use of diclofenac is therefore banned, yet still poses a significant threat, as the drug is occasionally available in large-animal formulations intended for humans. Habitat destruction and declining food availability are additional challenges. Vultures are slow breeders, with long gestation periods and a low rate of reproduction, so even under the best conditions; it will take years for



populations to fully recover.

Conclusion

- Flagship species play a pivotal role in conservation efforts by capturing public interest, fostering emotional connections with nature, and mobilizing resources for broader ecological protection. While they are often selected for their charisma and visibility, their impact extends far beyond individual species, serving as vital ambassadors for entire ecosystems. However, reliance on flagship species should be balanced with ecosystem-based approaches to ensure that conservation priorities are not skewed by popularity alone.
- By integrating flagship species strategies with scientific research and inclusive community engagement, conservation programs can harness both emotional appeal and ecological integrity, ultimately leading to more effective and sustainable outcomes for biodiversity preservation.

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Agroforestry: A sustainable solution for land degradation neutrality

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Introduction

Land degradation is a major global environmental challenge, with far-reaching consequences for soil fertility, biodiversity, and agricultural productivity. Unsustainable farming methods, deforestation, excessive grazing, and climate change are some of the causes.The United Nations Convention to Combat Desertification (UNCCD, 2022) states that degradation affects around 3 billion people and accounts for 20–40% of the world's land area. Declining land productivity, decreased carbon sequestration, loss of ecosystem services, heightened susceptibility to extreme weather events, and financial losses are all effects of land degradation. Water erosion accounts for 69% and wind erosion for 20% of the 121 million hectares (Mha) of degraded land in India alone (NAAS, 2009).

The idea of Land Degradation Neutrality (LDN) has surfaced as a way to preserve and enhance land resources throughout time in response to this urgent problem. A multifaceted strategy involving community involvement, regulatory changes, and sustainable land management techniques is needed to achieve LDN. Agroforestry has drawn a lot of attention among the different approaches to attaining LDN because of its capacity to improve soil health, repair degraded lands, boost biodiversity, and aid in the mitigation of climate change. By combining trees with crops and livestock, agroforestry offers a comprehensive land-use system that helps farmers financially while simultaneously enhancing ecological functions. The contribution of agroforestry to LDN is examined in this article, along with the scientific evidence for its efficacy.

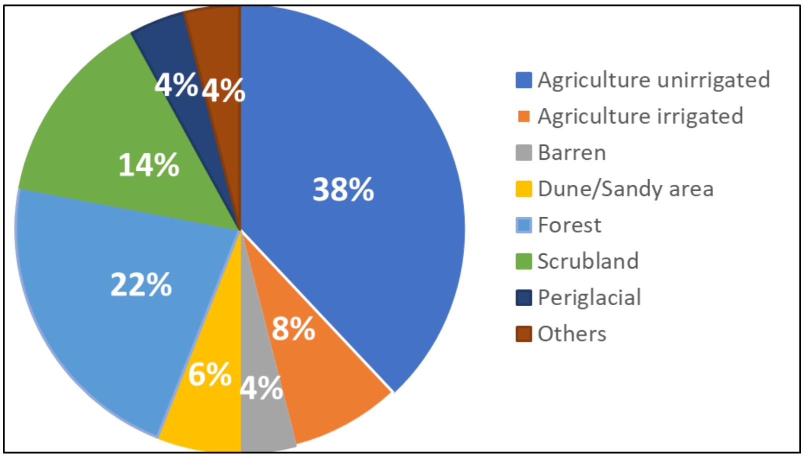

Fig. 1 Percent degraded land in India (SAC, 2021)

Understanding the Impact of Land Degradation

Land degradation is characterized by the deterioration of soil properties, loss of vegetation cover, decline in water availability, and depletion of nutrients essential for plant growth. This process results in lower agricultural yields, desertification, loss of biodiversity, and heightened food insecurity. The Millennium Ecosystem Assessment (MEA, 2005) defines land degradation as a state of continuous decline in ecosystem services over an extended period. According to IPCC (2019), land degradation affects 3 billion people worldwide, leading to economic losses and posing a direct threat to sustainable development. In India, 20-40 per cent of land is currently experiencing degradation, impacting 50 per cent of the world's GDP (UNCCD, 2022). Furthermore, land degradation puts 1.2 billion jobs at risk globally, representing 40 per cent of the world's workforce (ILO, 2022).

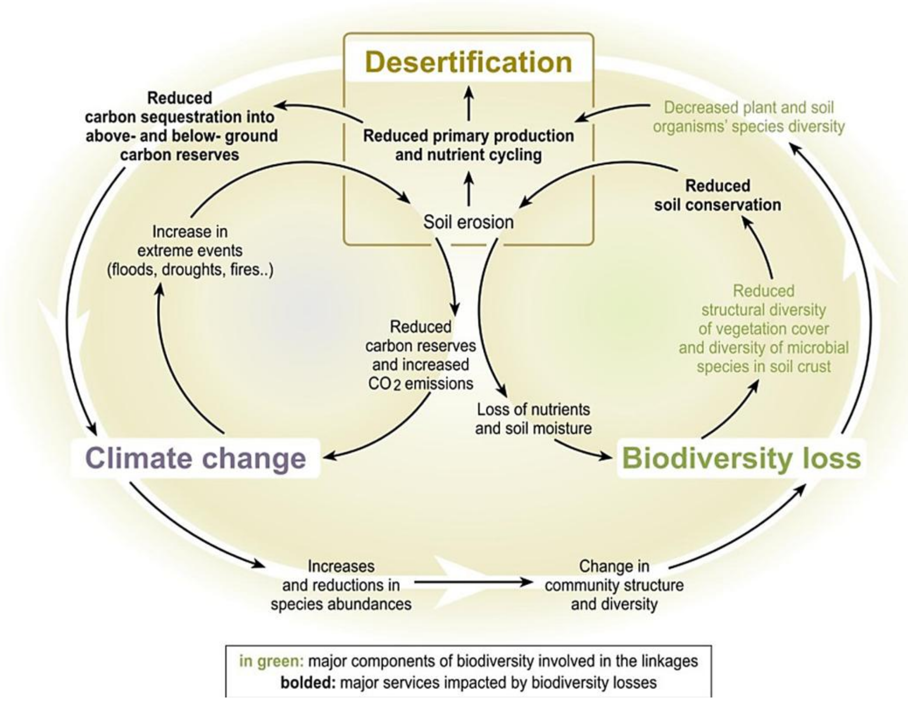

Fig 2: Systemic interactions driving environmental degradation

How Agroforestry Helps Achieve Land Degradation Neutrality (LDN)

Agroforestry is a key strategy for preventing, reducing, and reversing land degradation by integrating tree cover with agricultural landscapes. Research has demonstrated that agroforestry enhances soil structure, prevents erosion, improves water retention, and supports biodiversity. It plays a significant role in carbon sequestration, thereby mitigating climate change. Studies have shown that six-year-old Eucalyptus-based agroforestry systems sequester significant amounts of carbon (Singh *et al.*, 2022), helping reduce greenhouse gas emissions.

One of the primary benefits of agroforestry is soil conservation and erosion control.

Wind and water erosion are major causes of land degradation, particularly in semi-arid regions. Jinger *et al*. (2022) found that hedgerows and windbreaks in agroforestry systems significantly reduce soil erosion, thereby improving land productivity. Adhikary *et al*. (2017) reported that agroforestry interventions in shifting cultivated lands of eastern India enhanced soil organic matter and improved soil stability, ultimately reducing runoff and increasing water infiltration. Moreover, agroforestry practices contribute to reclamation of saline and acid soils. Study by Li *et al*. (2017) demonstrated that tree-based farming in saline wastelands improved soil properties through drip irrigation and salt-tolerant species, making the land suitable for crop cultivation.

Another critical function of agroforestry is carbon sequestration and climate mitigation. Trees in agroforestry systems act as carbon sinks, capturing and storing atmospheric carbon dioxide. ICRAF (2023) reports that agroforestry landscapes stores significantly more carbon than monoculture cropping systems. The sequestration potential varies across tree species, with Eucalyptus storing 43 Mg ha^{-1} of carbon, Casuarina sequestering 38.5 Mg ha^{-1}, and other mixed species storing 31.5 Mg ha^{-1}. These findings indicate that agroforestry systems not only restore degraded land but also help in climate adaptation and resilience.

Agroforestry models for land restoration

Different agroforestry models have been successfully implemented to restore degraded lands. Silvopastoral systems, which integrate trees with pasturelands, enhance fodder availability while reducing soil erosion. Alley cropping, a system where crops are grown between rows of trees, has been proven to improve soil fertility and increase crop yields. Windbreaks and shelterbelts, such as those studied by Prajapati *et al*. (2024), provide protection against wind erosion and enhance microclimatic conditions for crops. Homegardens, a traditional agroforestry system, contribute to food security and biodiversity conservation.

Additionally, agroforestry on reclaimed mining sites has been effective in restoring degraded lands. Kumar *et al*. (2015) examined vegetation succession on coal mine reclaimed lands in India and found that tree plantations significantly improved soil quality and biological productivity. Similarly, research by Mukhopadhyay *et al*. (2016) in the Jharia coalfield demonstrated that agroforestry interventions increased soil organic carbon and facilitated the natural recovery of plant species in degraded mining areas.

Challenges in implementing agroforestry for LDN

Despite its proven benefits, agroforestry faces several challenges. Policy and land tenure issues can hinder farmers from adopting tree-based farming due to unclear property rights. Initial investment costs and long gestation periods for tree crops also discourage smallholder farmers. Additionally, lack of technical knowledge and extension services limits the adoption of agroforestry practices. Market constraints, such as inadequate value chains for agroforestry products, further pose barriers to large-scale implementation.

Conclusion

Agroforestry offers a holistic and sustainable solution for achieving Land Degradation Neutrality (LDN). By integrating trees with agriculture, agroforestry enhances soil fertility, prevents erosion, improves water retention, sequesters carbon, and restores degraded lands. Scientific research and field studies have consistently demonstrated its effectiveness in tackling land degradation across diverse landscapes. With strong policy support, scientific innovations, and community engagement, agroforestry can play a crucial role in reversing land degradation and promoting climate resilience.

Governments and stakeholders must prioritize investment in agroforestry, strengthen extension services, and create favorable market conditions for agroforestry-based products. By doing so, we can ensure that degraded lands are restored, livelihoods are improved, and ecosystems are preserved for future generations. Agroforestry is not just a land-use strategy; it is a pathway towards a sustainable and resilient future.

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Agroforestry: A game changer for sustainable agriculture and climate resilience

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Introduction

In an era where the twin crises of climate change and environmental degradation threaten global food security, agroforestry has emerged as a promising solution that harmonizes agricultural productivity with ecological sustainability (Ghimire et al., 2024). Agroforestry, an age-old practice that integrates trees, shrubs, and other woody perennials with crops and livestock, offers a multifunctional approach to land use that enhances biodiversity, restores soil fertility, and sequesters carbon. It is increasingly recognized as a powerful tool to build climate resilience, support livelihoods, and contribute to sustainable agricultural practices (Vinodhini et al., 2023). The global agricultural landscape faces significant challenges. From land degradation and soil erosion to biodiversity loss and extreme weather events, farmers and policymakers are struggling to ensure food security without exacerbating environmental problems (Gupta, 2019). Conventional farming systems, often characterized by monocultures and heavy chemical inputs, have led to declining soil health, increased greenhouse gas emissions, and reduced resilience to climate shocks. These challenges demand innovative solutions that balance productivity with ecological integrity, and agroforestry stands out as a viable and sustainable alternative (Muhie, 2022). Agroforestry is not a novel concept. Traditional societies around the world have long practiced various forms of agroforestry, recognizing the benefits of integrating trees into farming systems. In many indigenous communities, trees were planted alongside crops to provide shade, improve soil health, and offer additional sources of food, medicine, and timber (Fahad et al, 2022). However, with the advent of industrial agriculture and the Green Revolution, the emphasis shifted towards maximizing crop yields through mechanization, synthetic fertilizers, and chemical pesticides. While these advancements significantly boosted food production, they also contributed to deforestation, soil depletion, and increased vulnerability to climate change. In response to these growing concerns, agroforestry is experiencing a revival as a sustainable and resilient approach to agriculture (Lin et al., 2011).

Agroforestry encompasses a diverse range of systems that integrate trees, crops, and livestock in various configurations. These systems can be broadly categorized into the following:

Agri-silviculture system

This system integrates trees with crops, allowing farmers to benefit from the complementary interactions between woody perennials and annual crops. Trees help improve soil fertility, reduce erosion, and provide additional income through timber, fruits, and nuts.

Silvipasture system

This system combines trees with livestock grazing. Trees provide shade and shelter for animals, reduce heat stress, and enhance pasture productivity. Silvipasture also improves soil structure and promotes carbon sequestration, making it a climate-smart approach to livestock farming.

Agri-silvipastoral system

It is a combination of trees, crops, and livestock; this system maximizes land use efficiency and diversifies farm income. The integration of multiple components enhances biodiversity and promotes ecological balance.

Windbreaks and shelterbelts

Trees are planted in rows or belts to protect crops and livestock from wind and soil erosion. These systems improve microclimatic conditions, enhance water retention, and create habitats for beneficial insects and wildlife.

Home gardens

Practiced in many tropical and subtropical regions, home gardens integrate trees, vegetables, herbs, and livestock within household spaces. They contribute to food security, provide medicinal plants, and support biodiversity conservation.

Each of these agroforestry systems offers unique benefits, depending on the specific ecological and socio-economic contexts in which they are implemented. What unites them is their ability to create synergies between different land-use components, resulting in greater overall productivity and resilience.

Environmental benefits of agroforestry

Agroforestry is widely recognized as an effective strategy for mitigating climate change and reversing environmental degradation. By integrating trees and shrubs into agricultural landscapes, agroforestry enhances carbon sequestration, improves soil health, and strengthens ecosystem resilience. Trees and shrubs absorb atmospheric carbon dioxide, storing it in their biomass and soils. This natural process helps offset greenhouse gas emissions, contributing significantly to climate change mitigation (Nayak et al., 2022). Additionally, agroforestry enhances soil fertility by promoting nutrient cycling, increasing organic matter content, and reducing soil erosion. The deep root systems of trees improve soil structure, enhance water infiltration, and prevent nutrient leaching, leading to healthier and more productive soils (Fahad et al, 2022). Agroforestry also fosters biodiversity by creating habitats for birds, pollinators, and other wildlife. The integration of diverse plant species supports ecological balance, strengthening natural pest control and pollination services essential for sustainable farming. Furthermore, trees regulate water cycles by reducing surface runoff, increasing groundwater recharge, and improving soil moisture retention—critical benefits for drought-prone regions facing water scarcity (Udawatta et al., 2019). In addition, agroforestry systems provide a natural buffer against extreme weather events such as floods, droughts, and storms. Tree cover protects against soil erosion, wind damage, and temperature fluctuations, enhancing the resilience of agricultural systems to climate change. By combining environmental sustainability with agricultural productivity, agroforestry offers a holistic approach to land management, ensuring long-term benefits for both farmers and ecosystems (Stetter and Sauer, 2024).

Socio-economic benefits of agroforestry

Beyond its environmental benefits, agroforestry offers substantial economic and social advantages that enhance farmers' livelihoods and drive rural development. By diversifying income sources—through timber, fruits, nuts, fodder, and medicinal plants—farmers reduce their reliance on a single crop, ensuring greater financial stability. The integration of trees and crops promotes year-round food production, mitigating hunger and malnutrition, especially in vulnerable communities (Ali et al., 2024). Additionally, agroforestry generates employment opportunities in tree planting, nursery management, agro-processing, and ecotourism, stimulating local economies. By naturally enriching soil fertility, it minimizes the need for synthetic fertilizers and pesticides, cutting input costs for farmers. Moreover, many traditional agroforestry practices hold deep cultural significance, fostering community bonds and preserving indigenous knowledge systems (Vinodhini et al., 2023).

Agroforestry for sustainable agriculture

Agroforestry, an age-old practice refined with modern ecological knowledge, involves the deliberate integration of trees and shrubs with crops and livestock to enhance productivity, improve soil health, sequester carbon, and increase biodiversity. Unlike conventional monoculture farming, which often leads to soil degradation, deforestation, and loss of biodiversity, agroforestry mimics natural ecosystems, promoting symbiotic relationships between various plant and animal species (Elevitch et al., 2018). By placing trees on farms, farmers can reduce soil erosion, enrich soil nutrients through nitrogen-fixing species, and provide shade that regulates temperature and moisture levels, thereby improving crop resilience to extreme weather conditions (Fahad et al, 2022). Additionally, trees provide shade and windbreaks, which create a more favorable microclimate for crops and livestock, reducing heat stress and improving productivity. Agroforestry systems also enhance soil health by adding organic matter through leaf litter and root biomass, promoting beneficial microbial activity, and reducing the need for synthetic fertilizers. One of the most significant benefits of agroforestry is its contribution to diversified income sources for farmers. Trees can yield fruits, nuts, timber, fodder, and medicinal products, providing additional economic benefits beyond traditional crops. This diversification reduces the financial risks associated with monoculture farming and increases resilience to market fluctuations and climate variability (Tebkew et al., 2024). Furthermore, agroforestry promotes food security by ensuring a continuous supply of edible products throughout the year. Various agroforestry practices, such as alley cropping, silvopasture, windbreaks, and home gardens, are tailored to different ecological and socio-economic conditions, making them adaptable to diverse agricultural landscapes. Agroforestry also supports wildlife conservation by creating habitat corridors for birds, insects, and other beneficial organisms, thus fostering ecological balance and pest control (Rahman et al., 2023). The practice reduces deforestation and land degradation by promoting tree planting on farmland instead of relying on clearing forests for agriculture. Moreover, agroforestry strengthens rural economies by creating employment opportunities in tree nursery management, timber processing, and agro-based enterprises (Tebkew et al., 2024).

Agroforestry for climate resilience

Agroforestry is a sustainable land management system that integrates trees, crops, and livestock on the same piece of land, enhancing climate resilience through multiple ecological and economic benefits. This practice mitigates climate change by sequestering carbon dioxide in trees and soil, reducing greenhouse gas emissions, and improving soil health. Trees act as carbon sinks, capturing CO_2 from the atmosphere and storing it in their biomass and roots (Mbow et al., 2014). Additionally, their presence reduces soil erosion by stabilizing the land, preventing nutrient loss, and enhancing water retention, which is crucial in areas prone to drought or heavy rainfall. Agroforestry also improves microclimates by moderating temperatures, reducing wind speed, and increasing humidity, creating favorable conditions for crops and livestock (Fahad et al., 2022). This approach diversifies income sources for farmers by providing timber, fruits, nuts, fodder, and medicinal plants, making them less vulnerable to economic shocks caused by climate extremes. Moreover, agroforestry enhances biodiversity by creating habitats for various species, including pollinators and natural pest predators, which contribute to ecological balance and sustainable food production. The integration of nitrogen-fixing trees enriches soil fertility, reducing the need for chemical fertilizers that contribute to environmental degradation (Song et al., 2021). Furthermore, trees in agroforestry systems serve as windbreaks, protecting crops from strong winds and reducing evaporation from the soil, thus conserving water resources. Agroforestry also promotes sustainable livestock management by providing shade, shelter, and nutritious fodder, reducing heat stress and improving animal productivity (Rolo et al., 2023). In arid and semi-arid regions, agroforestry plays a vital role in combating desertification by restoring degraded lands and enhancing groundwater recharge. Additionally, agroforestry supports climate adaptation by increasing resilience to extreme weather events such as floods, storms, and prolonged dry spells, ensuring food security for communities dependent on agriculture. The multifunctional nature of agroforestry allows for efficient land use while balancing environmental conservation with economic development (Jinger et al., 2023).

Conclusion

Agroforestry represents a paradigm shift in how we approach agriculture and land management. By integrating trees into farming landscapes, it offers a win-win solution for food security, environmental sustainability, and climate resilience. Despite its benefits, agroforestry faces challenges such as initial investment costs, long gestation periods for tree crops, and the need for technical expertise. However, these barriers can be addressed through government support, community participation, and research-driven innovations. Governments, non-governmental organizations, and research institutions are promoting agroforestry through incentives, training programs, and improved access to resources. Community participation and indigenous knowledge also play a crucial role in successfully implementing agroforestry practices, as many traditional farming systems already incorporate tree-based solutions. To realize its full potential, a multi-stakeholder approach is needed. Farmers require technical assistance and financial support to transition to agroforestry systems. Policymakers must integrate agroforestry into national agricultural strategies and provide incentives for tree planting. Researchers and extension services should work towards developing context-specific agroforestry models that maximize productivity and resilience. As the world grapples with the impacts of climate change and land degradation embracing agroforestry can pave the way for a more sustainable and resilient agricultural future. The time has come to recognize agroforestry not just as an alternative, but as a necessity for building a better world for future generations.

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Assessment of propagation techniques for *Albizzia lebbeck*

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Abstract

Albizzia lebbeck is a medium to fast-growing, drought-tolerant nitrogen-fixing tree, widely introduced and now found throughout the tropics It can tolerate saline, alkaline, and marginal soils and is used for timber, fuel, and fodder. *Albizia*, a subfamily of the Fabaceae family, is a versatile tree with over 160 species found in Asia, Africa, Madagascar, America, and Australia. It is also used in traditional medicine, timber, and fodder production. *Albizias* are small trees or shrubs with rapid growth and short lives, with colorful stamen-covered flowers and a sizable strap-shaped fruit.

Key words: *Albizzia lebbeck*, Agroforestry, Fast- growing, Phenology

Introduction

Agroforestry is a sustainable land and crop management system in India that aims to increase yields by growing arable crops, animals, and woody forestry crops on the same land unit. It includes conventional and contemporary land-use arrangements, creating jobs and value addition for rural and urban residents. Agroforestry systems have a great potential for sequestering carbon, they may act as a carbon sink and mitigate the negative effects of climate change on the planet., agroforestry in India has the potential to sequester 0.25 to 19.14 Mg C ha–1 yr^{-1}.

Ecology

Albizzia lebbeck is a dominating species in semi-evergreen vine forests (monsoon forest) that experience verydrywintersand meanannualprecipitationof 1300–1500 mm. Additionally, it can be discovered in semi-deciduous microphyll vine thickets on quartz sandstone mountain screes.Itisresilienttolong, hot, dry spells and harshwinters. The plant thrives in soils that cover basalt as well as among sandstone rocks and basalt outcrops on breakaway slopes. It is also found on the banks of riverine areas, low lateritic ledges above the coast, and stabilised dunes. After the first year, it is resistant to drought and moderate frost.

Environmental Requirements

India is home to a variety of climates, including hot and cold regions with temperatures up to 49°C and frost areas with a minimum temperature of -5°C.*Albizzia lebbeck*thrives in a range of climatic zones from sea level to 1500 m, with annual rainfall ranging from 600 mm to 2500 mm. However, it may also thrive in regions with low and erratic rainfall, as little as 300 mm per year.

Soiltype

This plant thrives on fertile, well-drained loamy soils but struggles with heavy clays. It can tolerate acidity, alkalinity, heavy, eroded, and waterlogged soils like shallow sandy, laterite, and loam laterite.

Botanical Features

Photo 1. Leaves, inflorescence, pods and seeds of *Albizia lebbeck*

General

*Albizzia lebbeck*is a deciduous tree with a grey fissured corky bark and reddish inner bark, reaching 15-20m tall and 1m in stem diameter. It grows in open spaces with multiple stems.

Foliage&Pods

The compound leaves are bipinnate, glabrous, and have 2-4 pairs of obliquely oblong leaflets. They are briefly stalked, initially bright green, and ripen to duller glaucous green. The dry season only lasts 4-6 weeks.The mature seeds are pale straw to

Phenology

light brown, 8-10 x 6-7 mm, orbicular or elliptic, and 6-12 in per pod, with a flat, transverse arrangement.

Inflorescences, flowers and fruits

The plant has fragrant, pedunculate flower heads in an inflorescence, with a fluffy, yellow-green inflorescence. The mature pods are narrow-oblong, papery-leathery, and indehiscent, with pale straw to light brown color. Seeds are brown, flat, orbicular, or elliptic, and can travel great distances through wind.

In India, flowering occurs mainly from March to May and fruits growto their full size from August to October. Plants grow from 0.5-2.0 m in height and 1.0-2.5 cm in stem diameter in 2-5 years, reaching 5 m/year under suitable conditions, and 2-2.2 m/year in dry tropics.During the wet season, trees continue to grow, flower, and germinate seeds, with mature pods remaining on the tree for three to four months.

Seed collection

Harvest ripe, healthy, and plentiful seed from January to March. Remove pods from trees using a long stick, and extract seeds by lightly beating them after sun-drying. Seed yield is half of 1 kilogramme.

Harvest

Pluck pods after last green areas disappear and light yellow, as ripe pods can be infested quickly. Early collection after ripening in shade minimizes harm. Brown, flat seeds per kg.

Processing and handling

Pods, often infested with insects, should be stored briefly and kept open during transport. They are dried in the sun, threshed, and cleaned using seed cleaning equipment. The process ensures ventilation and prevents insects from growing during storage.

Storage and viability

Seeds can be stored at room temperature with minimal moisture content for up to a year, and can be stored in sacks or polythene bags for 4 to 5 years.Studies conducted in the U.P. reveal 24.6 39.2% germination after 11 and a half years and 32.6% germination after 2 and a half years.

Dormancy and Pretreatment

Albizia lebbeck seeds, due to their tough coat, require pretreatment for germination. Various treatments, including dry heating, chemical scarification, mechanical scarification, warm water, and tap water, were investigated. Chemical scarification was the most effective, with 99% germination. High germination rates were also achieved by soaking seeds in heated water. Other commonpre-treatments for leguminous seeds include soaking in concentrated sulfuric acid for five minutes and 24 hours, as well as immersion in boiling water. Seeds are submerged in boiling water for 24 hours, germination can be increased by soaking in hot or cold water, and pods are soaked for 12 hours before planting.

Nursery Techniques

Seedlings can be raised in containers or nursery beds, with sunken beds used. Manure is added, soil pathogens tested, and fertiliser applied. Rhizobium and Azatobactor seed inoculation improves nodular mass, increasing dry matter production. Lime pelleting enhances this situation.Before sowing in the mother bed, immerse the seeds in cold water for two hours. After germination good seedlings should be transplanted. In 30 x 45 cmbags it attains 8 feet in six months. Seeds are sown in a mother bed, germinate from the third day, and after being pricked in polythene bags, 6 months old seedlings perform well in the field.

Direct Sowing

It occurs just before or at the beginning ofthe monsoon.You can seed in a properlyprepared patch, mound, pit, or line. The most common method, line sowing on completely loosening soil, can produce about 70% success if continuous weeding is started soon away.

EntireTransplanting

Seedlings develop quickly and reach 30 cm height for field planting in July. Survival rates range from 70-80, with better results in desert regions planting one-year-olds in the first half.

Stump Planting

Seedlings are transplanted from nursery beds at 8 cm tall, and stumps are created when plants are 15 months old and the second rainy season begins. Planting between mid-July and mid-August is best, with a 100% success rate. Plants reach 60-90 cm tall after first rains.

Vegetative Techniques

Vegetative propagation techniques are crucial for mass multiplication of multipurpose trees in agroforestry systems. A study developed a method for organogenesis-based in vitro regeneration of *Albizia lebbeck*, using exogenous hormones from mature trees and juvenile seedlings. Explants from young seedlings showed more callusing.The most effective dose of benzyl aminopurine (3 g/l) was found to produce callusing in epicotyl and hypocotyl explants in 1/2 Murashige and Skoog media. A BA concentration of 3 g/l was beneficial for shoot proliferation.

The study found that a medium with 6 g/l IBA alone had the best rooting success rates, while sand or vermiculite with yoshida solution was the best hardening medium. Tissue culture-raised plants had higher height, collar diameter, biomass, and root shoot ratio.

Silviculture Characteristics

*Albizia lebbeck*is a fast-growing, semi-deciduous, light and waterlogging tolerant tree suitable for tropics and subtropics, with moderate cold sensitivity and can be pruned or pollarded for a bushy crown.*Albizia lebbeck* has good pollarding and coppicing ability.

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Coconut crop conquerors: A close look at invasive insect pests in India

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Introduction

In the 21st century, one of the greatest global threats is biological invasions, which disrupt ecosystems and significantly impact socio-economic sectors. These invasions, driven by globalization, are escalating at an alarming rate, posing persistent threats to biodiversity, ecosystem services, and agricultural productivity.

In agriculture, invasive pests, pathogens, weeds, and vertebrate species cause substantial losses to crops, often thriving unchecked due to the absence of natural enemies in their new environments. An invasive species is an introduced organism that proliferates uncontrollably, adversely affecting habitats and ecosystems.

This chapter provides an overview of invasive or alien species that pose significant challenges to coconut crops (*Cocos nucifera* L.) (Table 1.), highlighting their impacts and the urgent need for effective management strategies.

Table 1: Invasive pest species on coconut

SL.NO.	Crop	Pest common name	Scientific name	Introduced from	Year of introduction	Current IUCN status
1.	Coconut	Rugose spiraling whitefly	*Aleurodicusrugiopercul atus*	Central America	2004	Invasive and devastating pest
2.		Red palm weevil	*Rhynchophorus ferrugineus*	Middle east	1891, 1917	Invasive and threatened species
3.		Coconut perianth red mite	*Aceriaguerreronis*	Mexico	1990	Invasive and threatened
4.		Rhinoceros beetle	*Oryctes rhinoceros*	South east Asia and Sri Lanka	1900	Invasive and endangered
5.		Coconut leaf beetle	*Brontispa longissimi*	Indonesia	1999	Invasive and threatened

6.		Bonders nesting whitefly	*Paraleyrodesbondari*	Uganda	2010	Invasive and devastating
7.		Black headed caterpillar	*Opisinaarenosella*	South Asia	1990	Invasive and damaging

(Selvaraj*et al*., 2019, 2020; Josephrajkumar*et al.*, 2023)

Rugose spiraling whitefly

Aleurodicus rugioperculatus Martin (Hemiptera: Sternorrhynca: Aleyrodidae)**:** This pest has its nativity with Central America and was seen around the year 2004 and from there itspreaded widely to India in the year 2017 and was reported as invasive and devastating pest in Tamil Nadu, Andhra Pradesh, Karnataka and Gujarat (Fig. 1.).

Nature of damage and symptoms

The infestation due to the pest was observed very severe in all the palms present in the field and lower leaves were mostly infested as compared to the middle and upper leaves. The population of RSW was observed on both tall and dwarf palms, but it was severe in dwarf and hybrid coconut palms.

Both nymphal and adult stage cause damage to the plant. The nymphs suck the sap from the leaves and adults colonize on the lower surface of the leaves and lays eggs in a spiral manner. Due to the feeding, it produces honey dew which results in sooty mold growth and affects the photosynthetic metabolism of the plant.

Current status

The invasive pest, *A. rugioperculatus* has already caused significant damage in the India. Currently, this pest has invaded mainly in coconut fields of Saurashtra region of Gujarat state and also Pollachi region of Tamil Nadu. The morphological and molecular identification lead to confirmation of first ever report of the new invasive pest, rugose spiraling whitefly *A. rugioperculatus* Martin (Hemiptera: Aleyrodidae) in coconut fields of Gujarat state, India. The current incidence of RSW in Gujarat is alarming due to its polyphagous nature and hence it has a great potential to extend its host range and spread to other coconut growing areas in the Gujarat state (Rao *et al*., 2018).

Management

1. Avoid transplanting of affected seedlings
2. Proper spacing
3. Encourage build-up of natural parasitoid *Encarsia*sp.
4. Targeting lower leaflets with water sprays.
5. Spray with 0.5% neem oil or 5% NSKE.
6. Installation of yellow sticky traps 15/ acre.
7. Build-up of natural predators like *Chrysoperlazastrowisillemi*and coccinellids.
8. Spraying with imidacloprid 0.005% in severe cases.

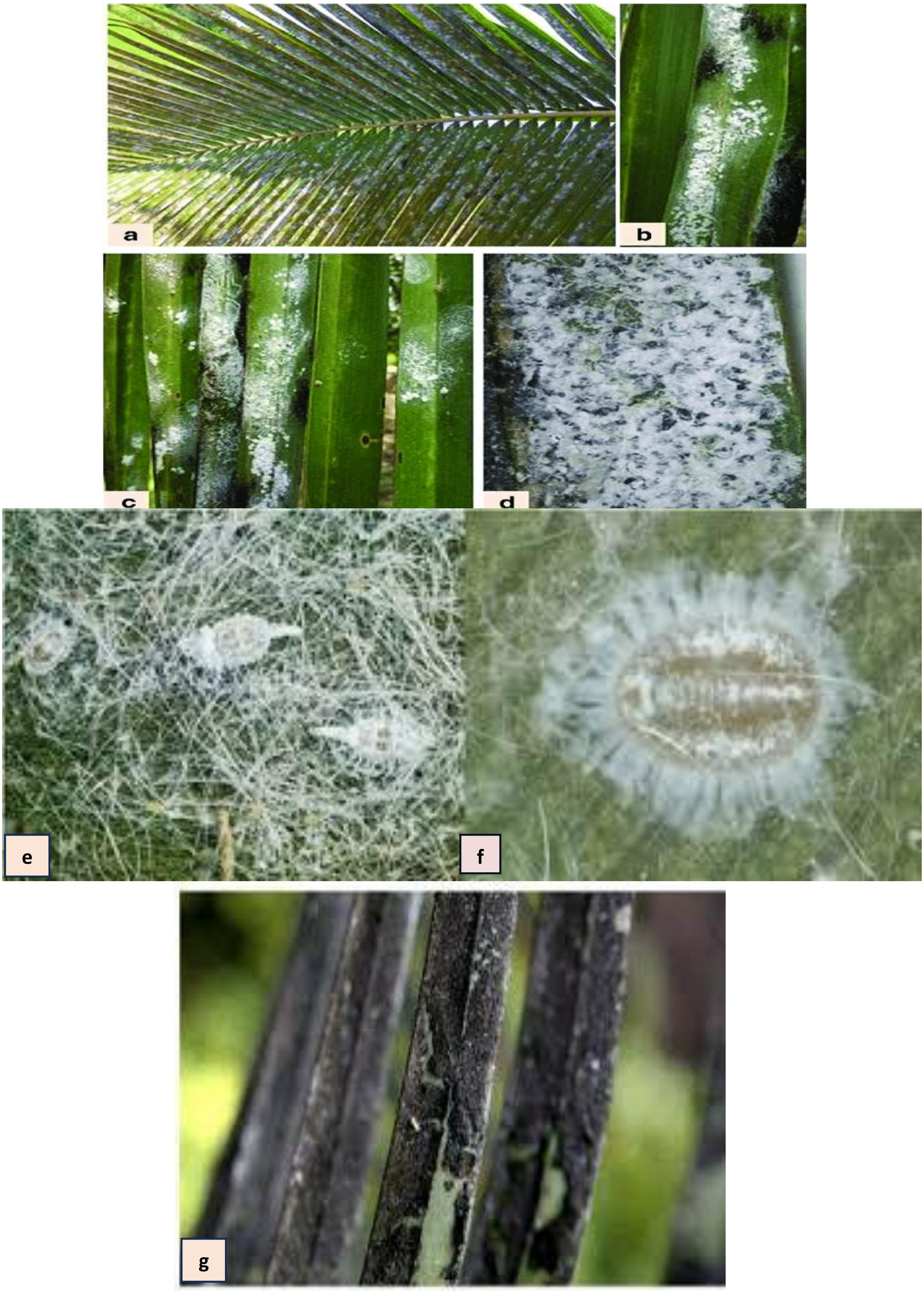

Fig. 1 Different live stages of *A. rugioperculatus* (a-d), closer view (e-f), sooty mold (g).

Red palm weevil

Rhynchophorusferrugineus(Coleoptera: Curculionidae)**:** This pest has its nativity to middle east around 1891 and widely spreaded to India and Malaysia in the year 1917. And from there it is being reported as invasive and threatened species around several parts of the world (Fig. 2).

Nature of damage and symptoms

It affects both younger and matured trees and causes ambiguous damage to the crown and causes the death of crown part of the plant.

Adult and grub stage cause the symptoms. It causes holes on trunk with brownish ooze, yellowing of inner leaves and gradual wilting of central shoot in the crown.

Current status

It has been recorded as serious invasive pest in parts of Malaysia and India(El-Shafie *et al*., 2020).

Management

1. Remove all wilted and damaged portion of stem and crown.
2. Fill the crown and axil of top three most leaves with a mixture of fine sand and neem powder 2:1 ratio.
3. Plug all the holes and inject 1% Carbaryl.
4. Root feeding with Monocrotophos.
5. Install pheromone traps Ferrolure @ 12/ ha.

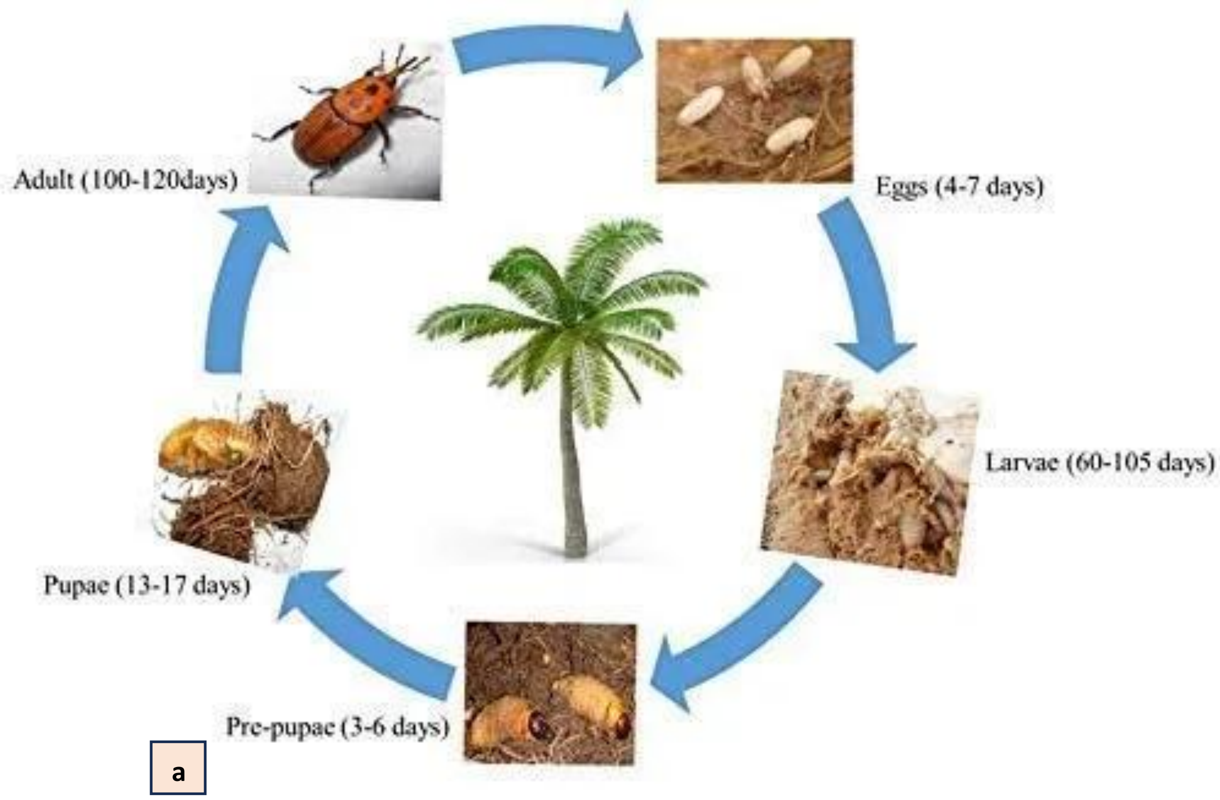

Fig. 2. Life cycle (a), Adult Weevil (b) and Damage symptoms (c)

Coconut perianth mite

Aceriaguerreronis, (Acarina: Eriophyiidae)**:**This pest has its nativity to Mexico and was introduced to India in the year 1990 through coconut imports and now it is a devastating pest in parts of Tamil Nadu, Karnataka, Kerala(Fig. 3.).

Nature of damage and symptoms

It is an important pest species of coconut, date palm and other palms. It affects the coconut trees during the button formation stage and young seedlings highly susceptible.

Triangularpaleyellowpatches close to perianth, necrotic tissues. brown coloured patches, longitudinal fissures and split on the husk. oozing of gummy exudation from affected part. malformed nuts and reduced size and copra content.

Current status

It is a serious pest in most of the eastern and western hemispheres of the world.

Recently caused heavy economical damage to the farmers in Hassan district of Karnataka (Naviaet al., 2010).

Management

1. Grow sun hemp as intercrop and casurina as border crop to prevent the air – borne mites.
2. Application of neem cake and organic manure.
3. Root feeding with TNAU Agro Biocide 30ml/tree.

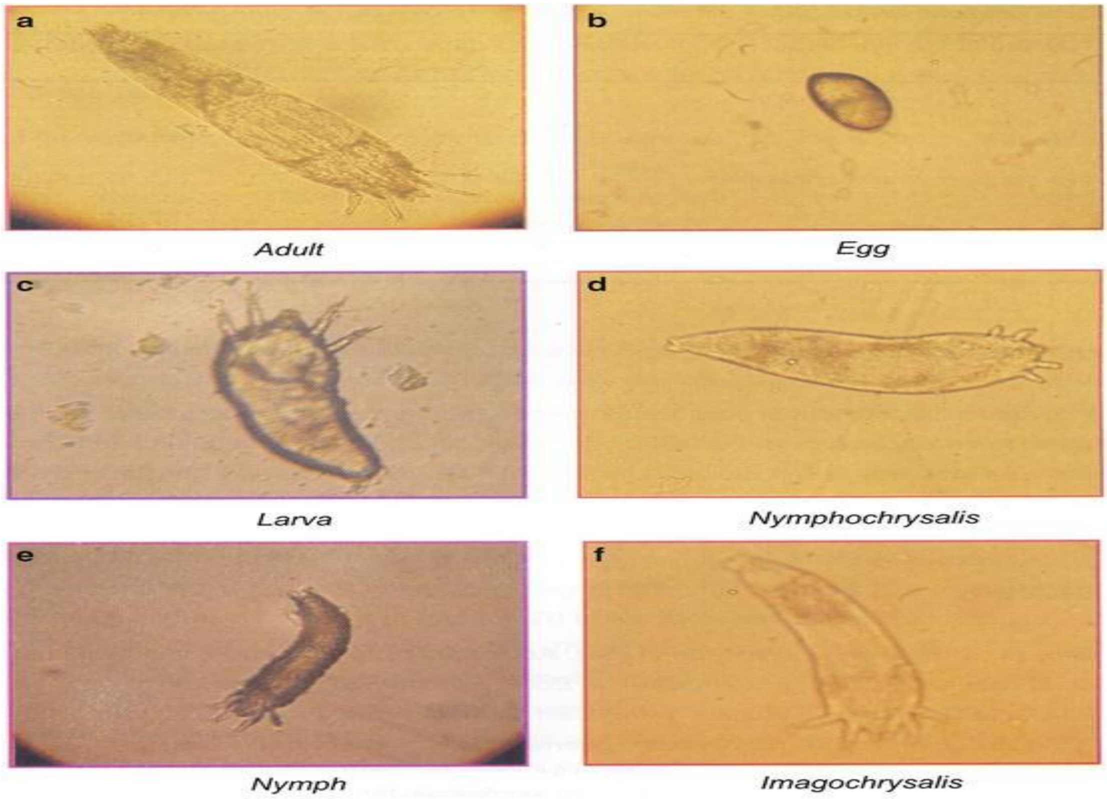

Fig. 3. Closer view of mites with different life stages (a-f)

Rhinoceros beetle

Oryctesrhinoceros (Coleoptera: Scarabaeidae)**:** This pest has its nativity to South East Asia and Sri Lanka and was introduced to India in the year 1900. From then it is considered as an invasive and damaging pest of coconut trees (Fig. 4).

Nature of damage and symptoms

Adult stage is the damaging stage and young seedlings and matured trees both are infected. Central spindles appear cut or toppled. Fully opened fronds showing characteristic diamond shaped or V– shaped cuttings. Holes with chewed fibre sticking out at the base of central spindle.

Current status

It is a serious pest all over southern India (Bedford, 2013).

Management

1. Maintain sanitation in coconut fields.
2. Collect and destroy various stages from manure pits.
3. Use of entamopathogenic fungi,*Metarhizium anisopliae*.
4. Examine crowns of tree and kill the adults.

5. Place Phorate 10 G in perforated sachets in the inner most leaf axil.
6. Set up Rhinolure pheromone traps @ 1/ ha.

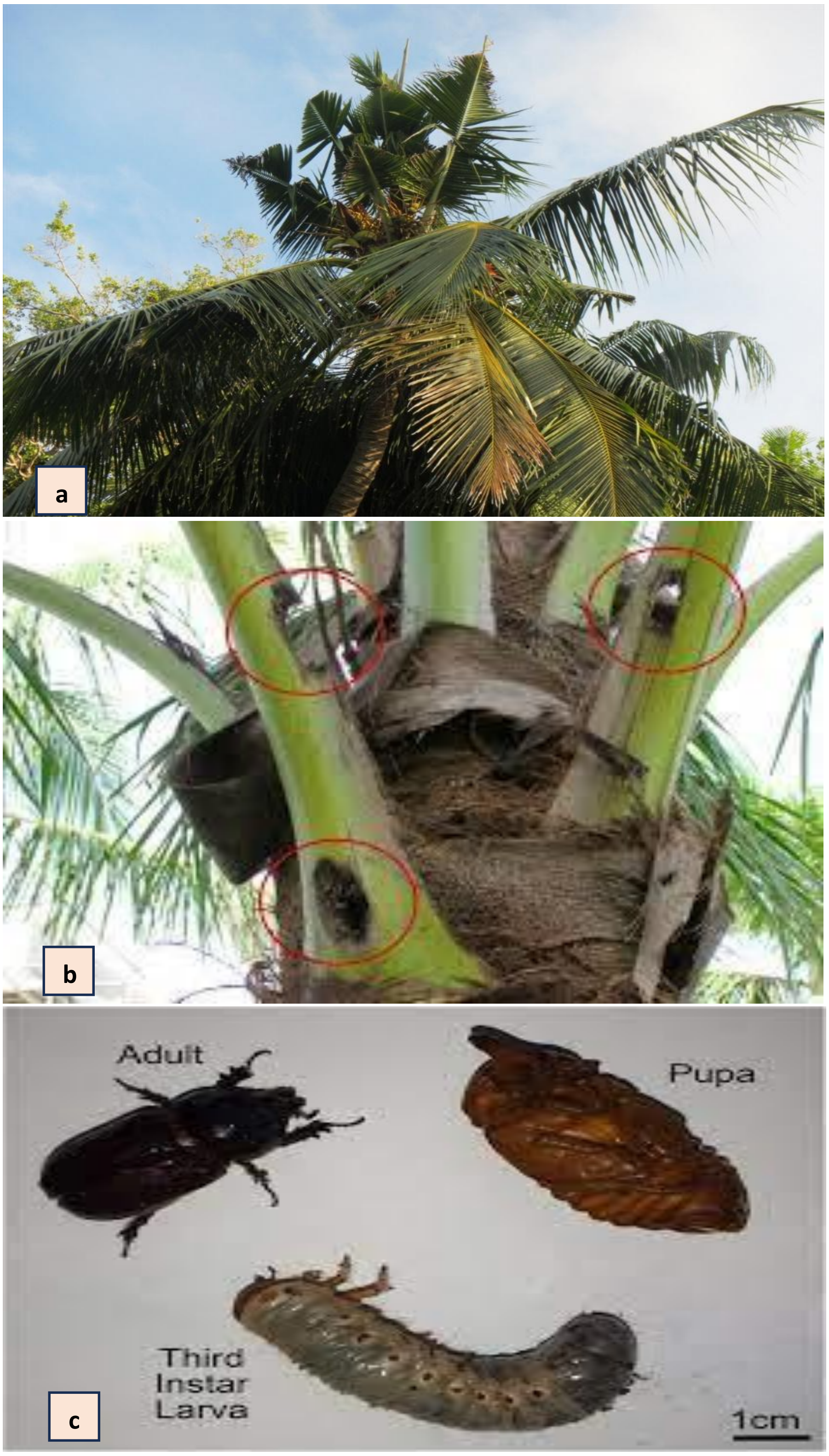

Fig. 4. Symptoms of infested palms (a), closer view of damage (b) and different live stages (c).

Coconut leaf beetle: - *Brontispa longissimi*(Coleoptera: Chrysomelidae)**:** This pest has its nativity to Indonesia and it has spreaded to India in the year 1999. It is an invasive and threatened species and causes serious economical damage (Fig. 5).

Nature of damage andsymptoms

The coconut leaf beetle (*Brontispalongissima*) is one of the most damaging pests of coconut and other palms. The larvae and adults of the beetle feed on the soft tissues of the youngest leaf in the throat of the palm. Affected leaves dry up, resulting in stunting of the palm and reduced nut production. Prolonged attacks on young palms can lead to their death. The beetle attacks more than 20 palm species with coconut (*Cocos nucifera*) being the most favored host.

The beetle attacks palms of all ages, but young palms are more susceptible than older ones, because the heart leaves of old palms are firmer and less suitable as breeding grounds for the beetle. Larvae of the beetle chew on large areas of the surface of leaflets still in the throat of the palm (the spear leaf), which causes the death of underlying tissues. Such leaflets show longitudinal white streaks. As the leaf emerges, the leaflets curl and turn brown, giving a characteristic scorched and ragged appearance. Photosynthesis is reduced to zero in affected leaflets. As the spear unfurls, the beetle moves on to other palms or the next emerging spear. The beetle does not attack leaves that emerge undamaged. Severe attacks destroy unopened leaves, affect growth of the palm and reduce its productivity. In most cases, all the central leaves of affected palms appear brown and fruit shedding is common in such palms. Stunted palms with less compact hearts are more susceptible to leaf beetle attacks.**Current status**It is widely spread and is a serious problem in Kerala and Tamil Nadu in India (Galicia*et al*., 2023).

Management

1. Blockading and cutting of coconut palms up to three kilometers from the infestation spot are done to prevent the beetle from spreading. The pest is also controlled by pruning, clean culture and proper disposal of infested coconut palms and parts thereof.
2. Several insecticides including imidacloprid, dieldrin, aldrin, phosdrin, aldicarb, dichlorvos, fenthion, monocrotophos, chlorfenvinfos, idiofenphos, trichlorophon, quinalphos, deltamethrin, dimethoate, cypermethrin, diazinon, azinophos, methidathion and chlordane are being used to control the coconut leaf beetle
3. Two parasitoids of coconut leaf beetle *viz*., *Tetrastichusbrontispae* and *Asecodeshispinarum*, have been successfully used in several countries to control the beetle.Use of the entomopathogenic fungus *Metarrhizium anisopliae.*

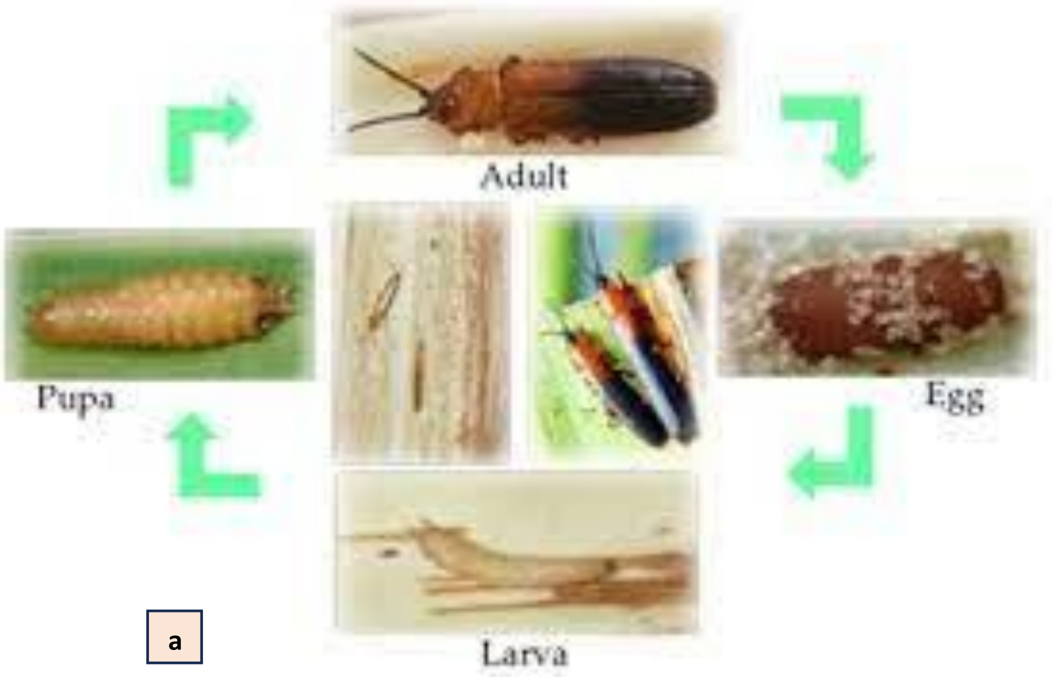

Fig. 5. Different live stages (a) and symptoms (b)

Bonder's nesting whitefly *Paraleyrodesbondari*, (Hemiptera: Sternorrhynca: Aleyrodidae)**:** This pest has its nativity to Uganda and it spreaded to India in the year 2010. It is from then onwards reported as invasive and threatened species (Fig. 6).**Nature of damage and symptoms: -** younger seedlings are mostly affected and lower leaves are infected first.

Adults and nymphs colonize in the lower surface and sucks sap and this results in honey dew secretion and finally results in secondary infestation by sooty mold fungus.

Current status

It was first reported on Ficus in India but now itis becoming a devastating pest of coconut palms (Mohan *et al*., 2019).

Management

1. Use of neem oil 0.5%.
2. Use of yellow sticky traps.
3. Use of systemic insecticide like dimethoate and imidacloprid.

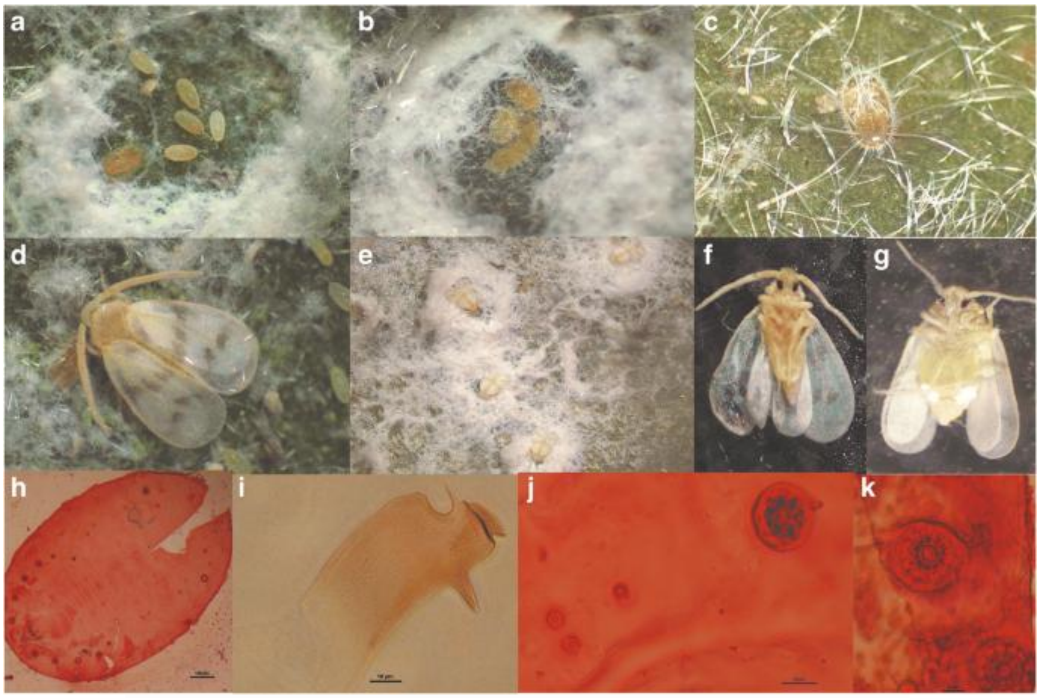

Fig. 6. Different live stages of bonder's nesting whitefly (a-k)

Black headed caterpillar

Opisinaarenosella (Lepidoptera: Chryptophasidae)**:** This pest has its nativity to South Asia and was introduced to India in the year 1990. From then it is reported as invasive and damaging pest on Coconut (Fig. 7).

Nature of damage and symptoms

Dried up patches on leaflets of the lower leaves showing burnt or scorching appearance. Galleries of silk and frass on underside of leaflet.

Current status

It is a damaging pest all over India (Lu *et al*., 2023).

Management

1. Release of *Goniozusnephantidis*.
2. Remove all infected leaves.
3. Root feeding with systemic insecticides.

Fig. 7. Larvae of black headed caterpillar (a) and symptoms in the plantation (b)

Conclusion

Invasive insect pests pose a significant threat to coconut cultivation, a vital crop for millions of farmers and industries worldwide. These pests not only disrupt the natural balance of ecosystems but also cause substantial economic losses by reducing crop yields and quality. Understanding their nature of damage, symptoms, and invasion pathways is crucial for devising effective management strategies. Integrated pest management (IPM) approaches, including biological control, cultural practices, and timely interventions, are essential to mitigate the impact of these invasive species. Strengthening quarantine measures, promoting research, and enhancing farmer awareness are vital to preventing future invasions.

By adopting eco-friendly and sustainable pest control solutions, we can protect coconut crops and ensure the livelihoods of those who depend on them, safeguarding the environmental and economic significance of this invaluable resource.

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Green credit programme

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Introduction

The Green Credit Programme (GCP) in India is a market-based voluntary initiative aimed at promoting environmentally sustainable practices by incentivizing the adoption of green technologies and processes. This program is part of India's broader strategy to enhance energy efficiency, conserve resources, and mitigate climate change impacts.

The Green Credit Rules 2023 have been notified by the Government of India on 12th October 2023 under the Environment Protection Act, 1986, as mechanism to encourage voluntary plantation activity across the country, resulting in award of Green Credits and to build an inventory of degraded land which can be utilised for Afforestation programmes. Hon’ble Prime Minister of India mentioned in the G20 summit in 2023 that “I feel this is the time to talk about green credit, India is working in this direction by developing Green Credit Framework through which we can initiate climate positive actions.” and “we should think towards how to develop business by using Green Credit Program, which is positive for developing ‘Pro Planet People’. (Kumar, 2024)

Objectives of the Green Credit Programme (GCP)

Encouraging voluntary tree Plantations

Encouraging voluntary tree plantation across the country serves a crucial purpose in addressing environmental challenges. Trees play a vital role in mitigating climate change, improving air and water quality, and preserving biodiversity. Tree planting not only enhances the aesthetic appeal of communities but also fosters a sense of environmental stewardship among citizens.

Meeting compliance requirements

Entities may provide funds to the Implementing agency for plantation activities, earning Green Credits (GCs) in return. These GCs, issued according to specific guidelines, can be utilized by the entity for accounting within the Environmental, Social, and Governance (ESG) and CSR framework.

Land inventory for Tree Plantation

This will serve the purpose of efficient and sustainable land use management. Building such an inventory allows for strategic planning and allocation of areas suitable for afforestation efforts, ensuring that the selected lands contribute effectively to ecological restoration

Ensuring Transparency

The GCP places a strong emphasis on transparency in all its processes. It ensures that the issuance of Green Credits and land records for plantation occur fairly and openly, building trust and confidence among program participants.

Promoting Inclusivity

The program is designed to be inclusive, welcoming a broad range of entities to participate. It extends its reach from individuals and small-scale initiatives to larger corporations and government bodies, fostering a collective commitment to environmental conservation.

Fostering a Greener and Sustainable Future

GCP seeks to contribute to a greener and more sustainable future. It does so by rewarding environmental stewardship which helps to mitigate the negative environmental impact of various activities.

Governance Structure

The Green Credit Programme is governed by a structured framework consisting of three key components: the Steering Committee, the Green Credit Programme Administrator, and Technical Committees. Each component plays a specific role in the effective implementation and oversight of the program. The role of each component is listed in the Notification

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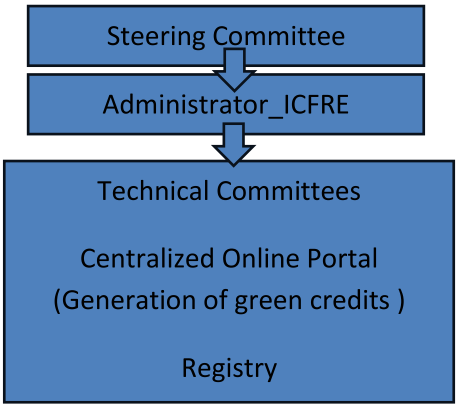

Who can get involved in GCP

Any entity (Government institutions/Public Sector Undertakings /Non-Government Organisations/Private Companies/Organisations/Philanthropies/Individuals/Group of Individuals registered under Societies Registration Act) can get involved in this program by registering on the dedicated GCP website.

Methodology (GCP Rule-2023-Moefcc)

1. The Forest Department of every State and Union territory shall identify degraded land parcels, including open forest and scrub land, wasteland and catchment areas, under their administrative control and management, which shall be made available for tree plantation to promote activities for increasing the green cover across the country forthe purposes of generation of Green Credit under the said Rules.
2. The land parcel identified for plantation above must be free from all encumbrances and must have size of five hectares or above.
3. Any person or entity desirous of undertaking tree plantation for the purposes of generation of Green Credit may apply to the Administrator.
4. On receipt of the application, the Administrator shall identify any land and assign the same to the applicant and require him to submit a proposal for undertaking tree plantationfor generation of Green Credit.

5. On receipt of the proposal, the Administrator shall prepare and issue a demand note to the applicant which shall include the cost of tree plantation and administrative expenses, if any, to be paid to theAdministrator within a period specified in the demand note.
6. The applicant shall pay the amount to the Administrator on or before the period specified in the demand notethrough a bank draft or such other means of payment as may be decided by the Administrator.
7. On the payment of the amount, the Administrator shall direct the Forest Department to carry out tree plantation in line with the management plan or working plan and shall be completed within a period oftwo years from the date of payment.
8. On completion of tree plantation, the Forest Department shall submit a report in this regard to theAdministrator and issue a certificate of completion of tree plantation to the applicant.
9. On receipt of the report, the Administrator, after evaluation and verification of the tree plantation activity may generate and issue Green Credit to the applicant under the said Rules, based on the totalnumber of trees planted in assigned land parcel and on the report and certification of completion of tree plantationactivity.
10. The Green Credit shall be calculated at the rate of one Green Credit per tree grown through the treeplantation on such land parcel, subject to minimum density of 1100 trees per hectare, based on the local silvi-climaticand soil conditions, on the certification of completion of tree plantation provided by the Forest Department concerned.
11. The Green Credit generated under the said Rules, may be exchanged for meeting the compliance of thecompensatory afforestation in case of diversion of forest land for non-forestry purposes under the Van (SanrakshanEvam Samvardhan) Adhiniyam, 1980 (69 of 1980), as applicable.
12. The Green Credit generated in lieu of tree plantation under the said Rules may be used for reporting underenvironmental, social and governance leadership indicator or under corporate social responsibility under theapplicable rules made under any law for the time being in force.

Outcomes

- It aims to enhance India’s forest and tree cover
- To Build an inventory of degraded land under the control and management of Forest Departments suitable for plantation.
- To encourage participation of individuals and entities in pro-planet actions by rewarding Green Credits.
- Critics argue that the GCP may facilitate the diversion of existing forests for non-forestry purposes, replacing them with monoculture

plantations that do not replicate the ecological value of natural forests. This approach could undermine biodiversity and ecological integrity. Additionally, the programme's reliance on market mechanisms without stringent safeguards may lead to the monetization of forests, prioritizing financial incentives over genuine conservation efforts. (sanctuary nature foundation)

In conclusion, while the Green Credit Programme represents a novel approach to promoting environmental sustainability, it necessitates robust frameworks to ensure that financial incentives translate into genuine ecological benefits. Addressing concerns related to ecological integrity, monitoring, Transparency (Karakkadayil Jose*et al*., 2025) and potential misuse is essential for the programme to achieve its intended environmental objectives.

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Hardwickia binata Roxb. - A resilient agroforestry tree for sustainable land use

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Introduction

*Hardwickia binata*Roxb.Commonly known as Anjan or Indian Black wood, is a resilient and multipurpose deciduous tree species native to the Indian subcontinent. It thrives in arid and semi-arid regions, making it a suitable tree component of agroforestry systems. It provides high-quality timber, fodder, and fuelwood while significantly contributing to soil conservation, carbon sequestration, and climate change mitigation. Its deep root system prevents soil erosion, enhances water retention, and improves soil fertility through nitrogen fixation, making it an ideal choice for degraded and dryland agroecosystems. By integrating *H. binata* into silvopastoral and agrisilvicultural systems, farmers can achieve sustainable income sources while enhancing ecosystem resilience (Sharma et al., 2018; Rao & Verma, 2020).

(A 30 year *Hardwickia binata* planation in Karnataka)

Silviculture and Agroforestry Compatibility

Adaptability to arid and semi-arid lands and the desirable growth characteristics of this tree make it an ideal choice for agroforestry in those areas. In general, the recommended spacing in agroforestry plantations may vary based on the intended use. For timber production purposes, 5m x 5m or 4m x 5m is used, but 10m x 10m is preferred for fodder production. To maximize the yield of poles and lumber, trees in border plantations are arranged in single or double rows, 4m apart. Commercial value is maximized when proper training guarantees straight growth with little forking (Chaturvedi et al., 2017).

Weeding must be done periodically throughout the establishment phase to lessen competition for nutrients and water. Legumes and other cover crops can be interplanted to improve nutrient cycling, reduce weeds, and retain soil moisture. A study in the Bundelkhand region of Rajasthan indicated the need for pruning to obtain knot-free timber, which should be carried out before the rabi season. Lopping for fodder yield is recommended annually, yielding approximately 20 kg of leaves per tree. According to Deb Roy et al. (1980), lopping should be restricted to the bottom two-thirds of the crown, and trees should rest for two seasons in order to maintain productivity. Its coppicing ability is comparatively low, yet even at an advanced age, H. binata shows good pollarding capacity. The best timber production is achieved through systematic thinning of high-density plantations (400–800 trees per hectare) (Chaturvedi et al., 2017).

Agroforestry Systems and Practices

Agroforestry systems incorporating *H. binata* play a crucial role in promoting ecological sustainability and enhancing rural livelihoods. The silvipastoral system integrates it with pasture grasses, offering shade and improving forage availability without significant competition for soil nutrients and water (Sharma et al., 2018). Similarly, the agri-silvicultural system supports intercropping with cereals, pulses, and oilseeds, reducing soil erosion while enhancing soil fertility through organic matter decomposition (Rao & Verma, 2020). These systems exemplify how *H. binata* contributes to sustainable land use by balancing agricultural productivity with ecological benefits.

Beyond traditional agroforestry models, it also plays a significant role in windbreak and shelterbelt systems, where it mitigates the impact of desiccating winds, reduces soil erosion, and improves microclimate conditions for crops (Bhatia et al., 2022). In mixed agroforestry systems, it enhances biodiversity by integrating with multipurpose species such as *Azadirachtaindica* and *Dalbergia sissoo*, thereby diversifying farm outputs (Joshi & Patel, 2021). Furthermore, *H. binata* is valuable for reforestation and land rehabilitation efforts, aiding in the restoration of degraded lands and increasing soil carbon sequestration, which strengthens climate resilience (Gupta et al., 2020). These diverse agroforestry applications highlight the species' adaptability and its potential to support both environmental conservation and sustainable agricultural practices.

Role in Sustainable Land Use

The role of *Hardwickia binata* in sustainable land use is defined by its ecological adaptability and resource efficiency. As a drought-resilient species, it thrives in low-rainfall areas, making it a valuable choice for afforestation efforts in water-scarce regions (Sharma et al., 2016). Its minimal resource requirements, including low water and fertilizer inputs, enhance its suitability for small-scale farmers seeking cost-effective agroforestry options (Bhatia et al., 2022). Additionally, *H. binata* contributes to biodiversity enhancement by supporting beneficial soil microorganisms and pollinators, thereby improving agroecosystem stability (Rao & Verma, 2019). Beyond its ecological benefits, the species also yields multiple products, including high-quality timber for construction and furniture, as well as medicinally valuable bark and leaves (Joshi & Patel, 2021).

The economic and industrial significance of *H. binata* further underscores its role in sustainable agroforestry and rural livelihoods. The species produces durable, termite-resistant timber used extensively in construction, furniture making, and agricultural tools (Sharma et al., 2018). Its bark serves as a rich source of tannins for the leather industry, while its gum has applications in pharmaceuticals and adhesives. Additionally, the leaves and pods of *H. binata* provide a crucial source of livestock fodder, particularly in drought-prone regions where fodder scarcity is a persistent challenge. Studies indicate that integrating it into agroforestry models can significantly enhance farm incomes by diversifying revenue streams from timber, fodder, and non-timber forest products (Meena et al., 2019). These attributes position *H. binata* as a key species for sustainable land management, contributing to both environmental conservation and rural economic development.

Challenges and Conservation Needs

Despite its numerous ecological and economic benefits, ***H. binata*** faces significant challenges, including overexploitation, poor natural regeneration, and slow growth rates. Addressing these issues requires a comprehensive conservation strategy that integrates community-led conservation initiatives, sustainable harvesting practices, and advancements in seed propagation techniques (Rao et al., 2022). These measures can enhance the species' long-term viability and facilitate its integration into sustainable land-use systems. Additionally, prioritizing ***it*** cultivation within governmental policies and agroforestry extension programs can support rural livelihoods while contributing to environmental sustainability. Policy interventions should focus on incentivizing farmers to incorporate ***it***into agroforestry models through financial support, technical training, and access to high-quality planting materials. Strengthening institutional frameworks and research efforts will be essential in ensuring the sustainable utilization and conservation of this valuable species (Das et al., 2021).

Future Prospects and Conclusion

With the growing emphasis on climate-smart agroforestry solutions, *H. binata* emerges as a critical species for sustainable land-use strategies. Its integration into agroforestry systems enhances biodiversity, strengthens ecosystem services, and provides economic stability for farming communities. Future research should focus on refining propagation techniques, optimizing management practices, and expanding value-added applications to maximize its ecological and economic potential (Mishra et al., 2023). The integration of *H. binata* into diverse farming systems creates resilient agricultural landscapes and ensures sustainability in land management; however, the combined efforts of policymakers, researchers, and farmers play a crucial role in promoting the widespread adoption of this potential timber tree.

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An overview of vegetation in Kanha Tiger Reserve

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Kanha National Park forms a part of the Central Indian highlands, which stretches from west to east through the state of Madhya Pradesh. The park is situated in two districts, occupying southern part of Mandla and north-eastern part of Balaghat districts. The core area of the park is roughly U-shaped with hill edges on three sides made by Maikal hills of Satpura range with series of lesser ridges of varying degree of slopes and grassy open pockets in the valley. The park area drains into Banjar river and its tributaries. Eastern drainage flows into river Halon, south-western drainage flows into river Banjar and north-western drainage flows into Salkum river.

According to Champion and Sett (1968), the forests of the park are categorized into 1) Moist Peninsular Sal Forests (3C/c2), 2) Southern Tropical Moist Mixed Deciduous Forests (3A/c2a) and 3) Southern Tropical Dry Mixed Deciduous Forest (5A/c2).

1.Moist Peninsular Sal Forests : The forest of this category is characterized by significant differences and represent to floristic of northern counterparts and partially to southern part. The Sal forest usually occupies well drained lower hills and slopes. Usually, ascending hill slopes provide congenial conditions for mixed forests. The good sal forest occurs on the porous, well drained, sandy loam derived from disintegrated mica-schist and gneisses in the valleys.The Sal (*Shorea robusta)* is a dominating species with other associates e.g. *Terminalia tomentosa, Anogeissus latifolia, Syzygium cumini, Pterocarpus marsupium, Madhuca latifolia, Lagerstroemia parviflora, Kydia calycina, Emblica officinalis, Qugeinia oojeinensis, Bridelia retusa, Terminalia chebula, Diospyros melanoxylon, Buchanania lanzan, Bauhinia malabarica, Casearia graveolens, Eriolaena hookeriana, Wendlandia exserta, Zizyphus xylopyrus, Randia dumetorum, Aegle marmelos* etc. in the tree canopy. In the under storey and ground vegetation some common species are *Phoenix acaulis, Collobrokia oppositifolia, Flemingia spp. Desmodium pulchellum, Woodfordia latifolia, Elephantopus scaber, Rungia pectinata, Euphorbia hirta, Asperagus recemosa, Sida acuta, Atylosia frutescens, Justicea crinita, Zingiber spp.,* etc. as ground herbs and shrubs. In the grasses, commom species are *Heteropogon contortus, Apluda varia, Dicanthium annulatum, Eragrostis viscose, Cynodon dactylon, Cyperus iria, Themeda quadrivalivs, Themeda trianda, Saccharum spontaneum* etc.

On the basis of varied soil and topography together, this type of forest is further sub-divided into two sub-types.

1. Moist Peninsular High Level Sal (3C/c2e (I))
2. Moist Peninsular Low Level Sal (3C2/c2e (II))

Moist Peninsular High Level Sal

The Sal being a dominant species in tree cover extends up to the undulating hills on laterite, trap and crystalline rock. Typical associates of this type of forests are *Terminalia tomentosa*, *Anogeissus latifolia*, *Syzygium cumini*, *Pterocarpus marsupium*, *Madhuca latifolia*, *Lagerstroemia parviflora* etc. However in the under storey, common shrubs are found to be *Indigofera pulchella*, *Phoenix acaulis* and moderately dense cover of grasses like *Themeda triandra*, *T. quadrivalvis*, *Bothriochola odorata*, *B. pertusa* etc.

Moist Peninsular Low Level (Valley) Sal

Generally, valley of the park area is covered by this type of forest. The forest is characterized by moderate shrub growth as an under storey. In the tree canopy, sal being a dominant species is associated with *Terminalia tomentosa*, *T. bellerica*, *Haldina cordifolia*, *Pterocarpus marsupium*, *Schleichera oleosa* etc. However, in the middle tree cover, the common associates are *Syzygium cumini*, *Ougeinia oogeinsis*. In the shrub layer, the common species are *Flemingia semialata*, *Flemingia nana*, *Indigofera pulchella*, *I. cassioides* etc. However, some common grasses viz. *Themeda quadrivalvis*, *T. arundinacea*, *T. triandra*, *Bothriochloa odorata*, *B. intermedia*, *Imperata cylindrical*, *Arthraxon quartinious*, *Oplismenus burmannii* are also found intermittently in open area.

Southern Tropical Moist Mixed Deciduous Forests

This type of forest occurs on lower slopes where soil depth is more and moisture regime is comparatively better. Floristically, the forest is representing to mixed forest. The floristic composition in various storeys is as under.

Top storey : *Gmelina arborea*, *Pterocarpus marsupium*, *Terminalia alata*, *T. chebula*, *Ficus bengalensis* , *F. arnottiana*, *Haldina cordifolia*, *Syzygium cumini*, *Schleichera oleosa*, *Terminalia tomentosa*, *Bridelia retusa*, *Grewia tiliifolia*, *Stereocarpum chelonoides*, *Madhuca indica*, *Garuga pinnata* etc.

Under storey : *Dendrocalamus strictus*, *Buchanania lanzan*, *Trema orientalis*, *Miliusa tomentosa*, *Madhuca indica*, *Gardenia latifolia*, *Cassia fistula*, *Lagerstroemia parviflora*, *Emblica officinalis*, *Grewia tiliaefolia*, *Butea monosperma*,*Diospyros melanoxylon*, *Careya arborea*, *Semecarpus anacardium*, *Woodfordia fruticosa*, *Garuga pinnata*, *Casearia elliptica*, *Mallotus philippensis*, *Ixora arborea* etc.

Southern Tropical Dry Deciduous Mixed Forests

This type of forests occurs extensively on 'dadars' and upper slopes of hills allover the park area. Common tree species found in this type are: *Sterculia urens*, *Radermachera xylocarpa*, *Launea coromandelica*, *Madhuca indica*, *Boswellia serrata*, *Aegle marmelos*, *Butea monosperma*, *Diospyros melanoxylon*, *Buchnania lanzan*, *Emblica officinalis*, *Ougeinia oogeinsis*, *cassia fistula* and *Catunaregam spinosa*. Common shrubs are *Carissa spinarum*, *Euphorbia nivulia*, *Murraya paniculata* etc. Among climbers, *Acacia pinnata*, *Ventilago denticulate*, *Cryptolepis buchanani* and *Hemidesmus indicus* are occasionally found.

Grasslands

The grassy meadows are important source of food for the sustenance of wild herbivores. Grasslands of the park are classified into three categories viz. i) those on ‘dadars’, ii) those on extensive valleys and iii) those on flat silted stream beds and supporting to variety of grasses. Some of the common grasses are: *Iseilema anthephroides, I. laxum, Themeda laxa, T. triandra* etc. The extensive meadows in the wide lower valleys exhibit excellent grasses. Main species are *Apluda mutica, Arundodonax, Bothriochloa intermedia, Capillipedium parviflora, Chionachne koenigii, Coix lacryma-jobi, Cymbopogon martini, Dicanthium caricosum, Eragrostiella brachyphylla, Eragrostis tenella, Heteropogon contortus, Imperata cylindrical, Iseilema antheproides, Ophiuros megaphyllus, Pennisetum hohenackeri, Sorghum nitidum, Themeda laxa, T. triandra* etc. In stream beds grasses grow very tall and the chief among them are *Thysanolaena maxima, Phargmatis karka, Themeda arundinacea, T. laxa, T. quadrivalvis, Saccharum spontaneum, Vetiveria zizanioides* etc.

The forests of the park area are one of the richest reservoirs of several plant genetic resources. Some plant species were observed to have ethno-medico values and are being used by local tribes (Gond and Baiga) to cure various ailments. Fifty such plants of ethno-medico importance are presented below.

Botanical name	Local name	Family	Habit	Medicinal uses
Abelmoschus crinitus	Jangli bhindi	Malvaceae	S	Seeds used as tonic carminative
Abrus precatorius	Gumchi	Papilionaceae	c	Roots and leaves sweetish, useful in leucoderma, skin diseases and wounds
Achyranthes aspera	Chirchita	Amarathaceae	H	Whole plant used in cough, asthma, enlarged spleen, malaria
Adhatoda zeylanica	Adusa	Acanthaceae	S	Whole plant used in cough, asthma, bronchitis, tuberculosis of lungs
Andrographis paniculata	Kalmegh	Acanthaceae	H	Whole plant useful in dysentery, diarrhea and malaria
Argemone mexicana	Pilikater	Papaveraceae	H	The plant is used as medicine in skin diseases
Asparagus racemosa	Satawar	Liliaceae	C	Roots used as aphrodisiac
Barleria prionitis	Katsarai	Acanthaceae	H	Roots and leaves used in glandular swelling

Biophytum sensitivum	Lajni	Oxalidaceae	H	Leaves, seeds and root used in diuretic wounds, gonorrhoea

Boerhavia diffusa	Punarnava	Nyctaginaceae	H	Roots are diuretic, laxative, febrifuga and purgative, used in jaundice
Calotropis gigantean	Aak	Asclepiadaceae	S	Whole plant anthelmintic, dropsy, asthma, cough and cold
Cassia tora	Chakora	Caesalpiniaceae	S	Leaves and seeds used in skin diseases, foul ulcers
Celastrus paniculatus	Malkangani	Celastraceae	S	Oil used externally in painful joints, hemiplegia, ulcers skin diseases, piles and also in headache
Centella asiatica	Bramha	Apiaceae	H	Whole plant used in leprosy, tuberculosis, brain tonic
Chlorophytum arundinaceum	Safed musli	Liliaceae	H	Used in impotency
Cissampelos pareira	Pudin bela	Menispermaceae	C	Roots are used in dyspepsia, diarrhea, dropsy, cough and urinary diseases
Clematis gouriana	-	Ranunculaceae	C	The roots and stems if bruised and applied to the skin cause visitation
Cleome gynandra	Chippa	Capparaceae	H	Leaves applied externally in rheumatism and roots used in fever
Costus speciosa	Keokand	Costaceae	S	Rhizomes astringent, purgative, stimulant
Crotalaria spectabilis	Khulkhula	Faceae	S	Plant used in scabis and impetigo
Cuculigo orchioides	Kali musli	Hypoxidaceae	H	Used in gonorrhoea, leucorrhoea, asthma, jaundice, diarrhea
Curcuma aromatica	Ganji	Zingiberaceae	H	Rhizomes used insprains, bruises and skin diseases
Dioscorea pentaphylla	-	Dioscoreaceae	C	Tubers useful to allay pain on swelling
Elephantopus scaber	Van tambaku	Asteraceae	H	Plants astringent, febrifuge, used in snake

				bite
Evovulus alsinoides	Sankhpushpi	Convolvulaceae	H	Anthemintic used in febrifige, fever and dysentery
Exacum tetragonum	Bada	Gentiaceae	H	Whole plant used in malarial fever
Flacourtia indica	Kakai	Flacourtiaceae	S	The fruits are sweet, appetizing and digestive
Gloriosa superba	Kalihari	Liliaceae	C	Tubers used as tonic, anthelmintic and to cure ulcer, piles and gonorrhoea
Grewia hirsute	Gursakari	Tiliaceae	S	Roots used in diarrhea and dysentery
Hedychium coronarium	-	Zingiberaceae	S	Useful in foetid, nostrils, anathelmintic, applied to swelling
Hemidesmus indicus	Anantmool	Asclepiadaceae	C	Blood purifier, used in fever,skin diseases and urinary complaints and rheumatism
Holarrhena pubescens	Dudhi	Apocynaceae	S	Used in amoebic dysentery
Lavandula binnata	-	Lamiaceae	H	Used in stings and bites from poisonous animal
Mucuna pruriens	Kiwanch	Faceae	C	Roots used in fever, seed powder as aphrodisiac
Nelumbo nucifera	Kamal	Nymphaeceae	AP	Used in cough, leprosy, blood defects and skin eruptions
Nyctanthes arbor-tristis	Siharu	Oleaceae	S	Leaves-aphrodisiac, laxative used in rheumatism,sciatica
Phyllanthus amarus	Bhuinaonla	Euphorbiaceae	H	Plant –diuretic used in jaundice, gonorrhoea and urinary tract
Plumbago zeylanica	Chitrak	Plumbaginaceae	S	Roots are used in diarrhea, dyspepsia, piles, leprosy and skin disease
Scoparia dulcis	Methi patti	Scrophulariaceae	H	Leaves used in fever, cough, cold, kidney

				stone, diarrhea, dysentery
Sida acuta	Kharenta	Malvaceae	H	Leaves – demulcent, diuretic, given in rheumatism pains and ulcers
Smilax zeylanica	Ramdatoon	Smilaxaceae	C	Roots used in rheumatism and dysentery
Spilanthes acmella	Akarkara	Astefaceae	H	The pungent flower heads are chewed to relieve toothache, throat and gum infection
Swertia angustifolia	Chirayata	Gentianaceae	H	Plant decoction febrifuge laxative given in stomach
Tridax procumbens	Bhringraj	Asteraceae	H	Leaves applied to boils
Uraria picta	Chippa	Fabaceae	H	Powder given in diseases of children
Urginea indica	Jangali piyaz	Liliaceae	H	Bulb cardiac, stimulant, diuretic, expectorant
Ventilago denticulata	Keotibel	Rhamnaceae	C	Root bark powder is carminative and given in stomach stimulant, useful as tonic
Woodfordia fruticosa	Surteli	Lythraceae	S	Astringent and dysentery, stimulant given in pregnancy
Ziziphus maturitiana	Ber	Rhamnaceae	S	Fruit pulp used as poultice on hard boils, seed useful in diarrhea
Zingibar capitatum	Jangali adrak	Zingiberaceae	S	Rhizomes used in asthma and cold

AP – Aquatic plant, C – Climber, H – Herb, S – Shrub

Published by:

Impact Factor

SJIF: 2022-6.071

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