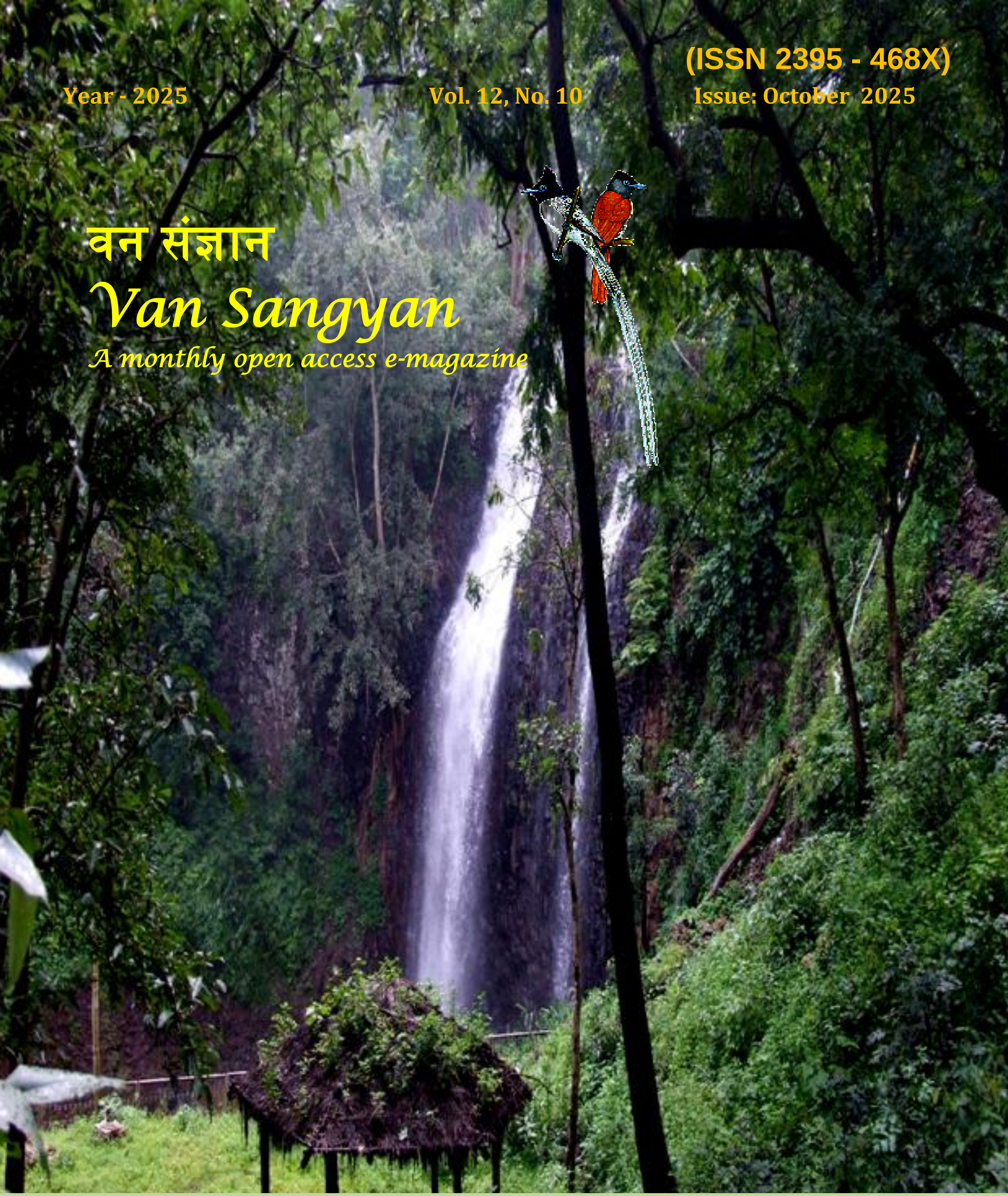
(ISSN 2395 - 468X)
Year - 2025 Vol. 12, No. 10 Issue: October 2025

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

Van Sangyan

Note to Authors:

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

by e-mail to vansangyan_tfri@icfre.org

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

The articles can be in English, Hindi, Marathi, Chhattisgarhi and Oriya, and should contain the writers name, designation and full postal address, including e-mail id and contact number.

TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

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

From the Editor's desk

*Agroforestry has emerged as a scientifically robust and ecologically transformative land-use strategy that significantly enhances soil health and soil fertility by integrating trees, crops, and sometimes livestock into a unified production system. Long-term studies indicate that tree-based systems increase soil organic carbon by 20–30% compared to monoculture agriculture, primarily through continuous leaf litter deposition, deeper root biomass, and improved nutrient cycling. Nitrogen-fixing species such as *Gliricidia sepium* and *Leucaena leucocephala* can add 50–200 kg N ha^{-1} yr^{-1} to the soil, while improved soil structure and microbial biomass boost nutrient mineralization rates and water-holding capacity. Agroforestry buffers soils against erosion—reducing soil loss by up to 50–80% on sloping lands—and enhances cation exchange capacity and pH stability, creating a more resilient agroecosystem capable of sustaining productivity under climate stress. As global agriculture confronts declining soil fertility, biodiversity loss, and climate uncertainty, the integration of agroforestry offers not only a pathway to regenerative land stewardship but also a scalable, science-backed solution for restoring the biological and chemical integrity of soils for future generations.*

In line with the above this issue of Van Sangyan contains an article on Impact of agroforestry on soil health and soil fertility. There are also useful articles viz.. Grewia optiva: The wonder tree of the Himalayas, Forests on the move: महिलाओं की कृषि वानिकी में भूमिका: सशक्तिकरण एवं पर्यावरण संरक्षण, Unlocking the potential of Bael: Addressing pests, diseases, and physiological disorders, Geotourism championing the environmental practices, Willow variety registration in India: Genetic resource conservation, DUS advances and farmer clone recognition, The silent ascent of trees due to changing climate, Annatto seeds as a natural dye source for cotton fabric, Tamarind (Tamarindus Indica L.): A multipurpose tree species for agroforestry, nutrition, and sustainable land use

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

Disclaimer – Van Sangyan

Statement of Responsibility

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

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

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

Contents **Page**

Impact of agroforestry on soil health and soil fertility

Satya Prakash Vishwakarma[1], R. K. Prajapati[2] and Pallavi Netam[1]

[1]Mahatma Gandhi Udyanikee Evam Vanikee Viswavidyalaya
Durg, Chhattisgarh
[2] Indira Gandhi Krishi Vishwavidyalaya
Krishak Nagar, Raipur, Chhattisgarh 492012
E-mail: spbhujnp@gmail.com

Introduction

Since its inception as a scientifically-recognized discipline and practice it has been widely acknowledged that agroforestry has the potential to enhance soil quality(Young 1989; Nair 2011).In the tropics and temperate regions of the globe, agroforestry practices have been promoted for decades due to their perceived benefits of not only improving soil quality, but also providing other ecosystem services (Jose, 2009). It illustrates the function of Agroforestry as a sustainable land management strategy that can enhance a number of common soil health indicators. We have divided the papers into three categories, with the first group discussing Agroforestry's function in enhancing soil organic carbon (SOC), the second group discussing soil nutrient enrichment, and the third group focusing on soil biota.

Healthy soil is arguably one of the most critical resources for the health of natural and agro ecosystems so that they can sustain food production as well as provision of ecosystem services. Although the term ‘soil health’ has been used synonymously with soil quality, Doran et al. (1996) defined soil health as ‘‘the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health.’’ According to the USDA, soil health is ‘‘the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans’’ (USDA-NRCS 2018). Within the array of benefits brought by trees, an important element is the positive effect of trees on soil properties and consequently benefits for crops the presence of trees in farming systems, although an ancient practice began to gain institutional attention during the 1970s and 1980s, with the beginning of studies on “agroforestry systems”. One of the principal definitions employed in this context was that proposed by Lundgren and Raintree in 1982: “Agroforestry is a collective name for landuse systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In Agroforestry systems there are both ecological and economical interactions between the different components. While trees in general can provide a number of environmental benefits in both rural and urban landscapes, and play key roles in ecosystem services provided by natural areas benefits that trees can provide on rural properties such as food security, household income, economic stability, and thermal comfort (shade) are most often associated with their products, such as fruit, timber, or other items, the inclusion of trees in agricultural systems can also optimize nutrient cycling and have positive effects on soil chemical and physical properties. This process is especially important in tropical soils, where a high degree of weathering has created deep, leached soils that are poor in plant nutrients (Ricklefs 1996). Although poor in nutrients, tropical soils are very rich in biodiversity, with higher diversity and biomass of microorganisms than temperate soils, with these being the principal agents mediating the supply of nutrients to the soil by means of the decomposition of organic matter, derived from the vegetation

In agricultural systems practiced by traditional peoples, this limitation is circumvented by using the land for a short period (generally 2- 3 years), after which the cultivated areas are left to fallow with natural regeneration of secondary vegetation. The associated ecological interactions reestablish nutrient cycling and recuperate soil qualities, after which the area can once again be used for agriculture (Kleinman et al 1995).

Agroforestry has great potential for offsetting the fodder and soil nutrient imbalances arising from forest degradation. However, the promotion of Agroforestry has never been a priority issue in the national agricultural and forestry department plans (Shah, 1996).

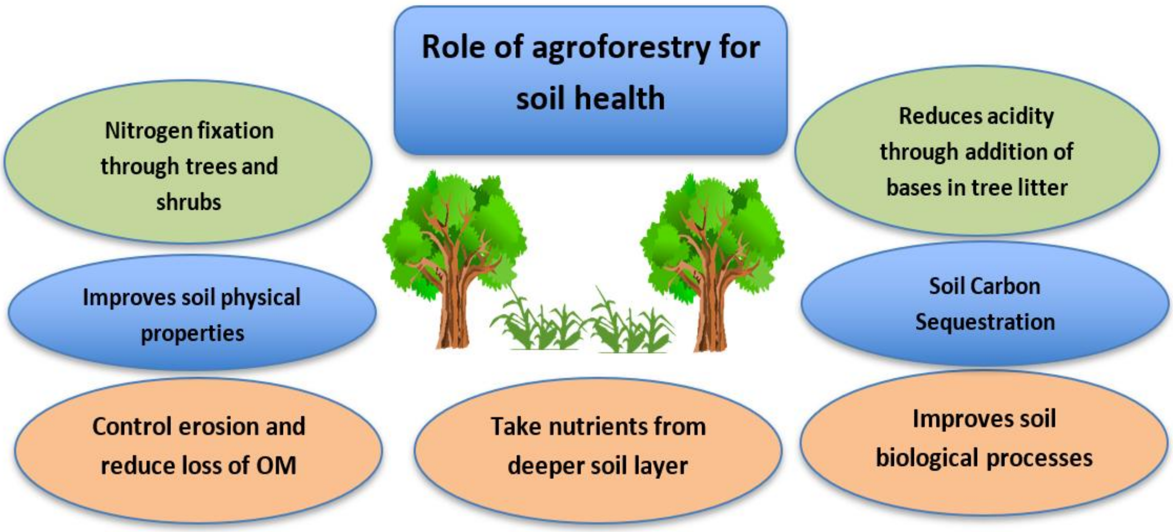


Figure 1 Role of agroforestry for improvement of soil health

Influence of trees on soil fertility

Agroforestry can contribute to all these aspects and has a major role to play in some. The capacity of trees to grow under difficult climatic and soil conditions, coupled with their potential for soil conservation, gives agroforestry a potential in the main types of marginal lands: semiarid, sloping and those with soil constraints. There is a demonstrated potential for reclamation of degraded land. Tree litter and prunings can substantially help to maintain soil organic matter and improve physical properties and at the same time supply nutrients. The contrast between natural and agricultural ecosystems suggests a high potential for agroforestry to lead to improved nutrient cycling and hence fertilizer use efficiency.

Trees producing litter rich in Ca were associated with soils with greater pH, exchangeable Ca, and per cent base saturation, as well as greater rates of forest floor turnover and greater diversity and abundance of earthworms.

The role of Agroforestry in maintenance of soil fertility

1. The soil that develops under natural forest and woodland is fertile. It is well structured, has a good water-holding capacity and has a store of nutrients bound up in the organic matter. Farmers know they will get a good crop by planting on cleared natural forest.
2. The cycles of carbon and nutrients under natural forest ecosystems are relatively closed, with much recycling and low inputs and outputs.
3. The practice of shifting cultivation demonstrated the power of trees to restore fertility lost during cropping.
4. Experience of reclamation forestry has demonstrated the power of trees to build up fertility on degraded land.
5. **A woody perennial suitable for soil fertility maintenance or improvement**
6. A high rate of production of leafy biomass.
7. A dense network of fine roots, with a capacity for abundant mycorrhizal association.
8. The existence of deep roots.
9. A high rate of nitrogen fixation.
10. A high and balanced nutrient content in the foliage; litter of high quality (high in nitrogen, low in lignin and polyphenols).
11. An appreciable nutrient content in the root system.
12. Rapid litter decay, where nutrient release is desired, or a moderate rate of litter decay, where maintenance of a soil cover is required.
13. Absence of toxic substances in the litter or root residues.
14. For soil reclamation, a capacity to grow on poor soils.
15. Absence of severe competitive effects with crops, particularly for water.

Effects of Trees on Soils

The capacity of trees to maintain or improve soils is shown by the high fertility status and closed nutrient cycling under natural forest, the restoration of fertility under forest fallow in shifting cultivation, and the experience of reclamation forestry and Agroforestry. Soil transects frequently show higher organic matter and better soil physical properties under trees.

Trees improve soil fertility by processes which:

- Increase additions to the soil;
- Reduce losses from the soil;
- Improve soil physical, chemical and biological conditions.

The most important sets of processes are those by which trees:

- Check runoff and soil erosion;
- Maintain soil organic matter and physical properties;
- Increase nutrient inputs, through nitrogen fixation and uptake from deep soil horizons;
- Promote more closed nutrient cycling.

The following are the principal trees and shrubs that have been employed for soil improvement.

Names in parentheses are synonyms formerly in use.

S. No.	Species	S. No.	Species
1	*Acacia auriculiformis*	20	*Leucaena leucocephala*
2	*Acacia mangium*	21	*Melaleuca leucadendron*
3	*Acacia nilotica*	22	*Parkia biglobosa (Parkia africana)*
4	*Acacia senegal*	23	*Peltophorumdasyrrachis*
5	*Albizia lebbeck*	24	*Populus deltoides*
6	*Albizia saman (Samanea saman)*	25	*Prosopis chilensis*
7	*Anacardium occidentale*	26	*Prosopis cineraria*
8	*Alnus spp.*	27	*Prosopis juliflora*
9	*Azadirachta indica*	28	*Prosopis tamarugo*
10	*Cajanus cajan*	29	*Senna reticulata*
11	*Casuarina cunninghamiana*	30	*Senna siamea (Cassia siamea)*
12	*Casuarina equisetifolia*	31	*Senna spectabilis (Cassia spectabilis)*
13	*Casuarina glauca*	32	*Sesbania bispinosa*
14	*Dalbergia sissoo*	33	*Sesbania grandiflora*
15	*Dactyladeniabarteri (Acioabarteri)*	34	*Sesbania rostrata*
16	*Dendrocalamus spp.*	35	*Ziziphus mauritiana*
17	*Erythrina orientalis*	36	*Ziziphus nummularia*
18	Flemingiacongesta (Flemingia macrophylla)	37	*Zizyphus spina-christi*
19	*Grevillea robusta*	38	*Leucaena leucocephala*

Trees add organic matter to the soil system in various manners, whether in the form of roots or litterfall or as root exudates in the rhizosphere (Bertin et al 2003). These additions are the chief substrate for a vast range of organisms involved in soil biological activity and interactions, with important effects on soil nutrients and fertility. Although carbon (C) constitutes almost 50% of the dry weight of branches and 30% of foliage, the greater part of C sequestration (around 2/3) occurs belowground, involving living biomass such as roots and other belowground plant parts, soil organisms, and C stored in various soil horizons (Nair et al 2010).

Although the ability of soils to accumulate C is generally related to characteristics that are little influenced by management, such as texture, some management practices can influence soil C sequestration, particularly the insertion of trees in agricultural systems. Soils in various sites studied by (Takimoto et al 2008)in the African Sahel were not markedly different among each other in terms of their characteristics such as pH, bulk density, and particle size, such that variations in their C contents seemed to be related to the influence of trees. In systems where trees were present for more than 30 years (parklands), there was a predominance of soil C in smaller fractions (<53 μm), which are more stable and thus represent a more "protected" form of C.

In India home gardens levels of soil organic C to be 30% and 114% greater than in coconut plantations and rice paddies, respectively, when home gardens where small (less than 0.4 ha) and levels 18% and 94% greater in larger home gardens (larger than 0.4 hectares). C levels in pasture soils can be greater than under systems with trees due to the faster turnover of the grass root system, as well as the greater bulk density of soils in pasture systems, that can lead to higher C values than found in less dense soils.Climate conditions also affect C accumulation in soils, since temperature and humidity greatly affect the activity of microbial communities and the breakdown of organic matter (Nair et al2009).

Trees and Soil Biodiversity

Soil macro invertebrates are sensitive indicators of natural systems, land use, and management, with agroforestry systems presenting a greater abundance and diversity when compared to other forms of agricultural land use. Agro forestry systems encompass a range of practices, such that there is considerable variation in the quality of organic matter produced and the effects of vegetation on soil humidity and temperature regime, with significant effects on the soil macro fauna community (Barros et al, 2008).

Trees on Tropical Soils

In contrast to temperate ecosystems, where soils generally are more fertile and a greater part of the nutrients is supplied by the weathering of parent material, conditions of high temperatures and rainfall in the tropics accelerate soil processes, including loss of nutrients, so that the greater stock of nutrients is found held in the biomass and made available through decomposition. The high temperature and humidity of tropical climates are conducive to the decomposition of organic matter, so that there is not only the release of nutrients but also the formation of negatively charged particles, which help to retain cations such as K, Ca, and Mg and maintain them in constant interface with the soil solution, where they can be absorbed by plants. In tropical systems, therefore, a soil cover of organic matter is essential to maintain adequate conditions for the soil micro, meso, and macro fauna that carry out this cycling (Lavelle et al 2001). As such, many of the studies on the effects of trees on tropical soil concentrate on the importance of organic matter made available in great part through litter fall.

Litter production can be a very important contribution in systems where perennial crops such as cacao and coffee are grown under the shade of trees. When compared to other agricultural systems in tropical conditions, agroforestry can accumulate greater amounts of carbon and can help maintain soil fertility through a more efficient cycling of nutrients and a reduction of losses through leaching and erosion.

In a number of situations, intercropping with legume species that fix atmospheric N means that this element will be provided through decomposition to other plants, a practice commonly known as "green manuring" (Schroth et al 2001). The great variety of legume species with potential for use as green manures offers a number of possibilities for intercropping. Quick-growing herbaceous species include *Cajanus cajan*, *Crotalaria juncea*, *Stizolobium aterrimum*, and *Calopogoniummucunoides*, which decompose rapidly and improve soil within 2-3 months. In contrast, tree legumes with slower growth, such as *Gliricidia sepium* and *Leucaena leucocephala*, are important for supplying organic matter with different characteristics, such as greater C/N ratios, polyphenol, or lignin contents. While organic matter with a low C/N ratio will decompose more quickly and rapidly releasing nutrients for use by crop plants, in certain situations a slower decomposition rate may be desirable, in order to maintain soil cover and control growth of weeds (Neves et al, 2003, Bergo et al 2006).

Role of agroforestry in soil quality/heath

Compared to natural, a managed agricultural ecosystem has greater amounts of nutrient flowing in and out, less capacity for nutrient storage, and less nutrient recycling. The capacity of trees to maintain or improve soils is shown by the high fertility status and closed nutrient cycling under natural forest, the restoration of fertility under forest fallow in shifting cultivation, and the experience of reclamation forestry and agroforestry (Young, 2003). The processes by which trees maintain or improve soil fertility are given below:

1. Photosynthetic fixation of carbon and its transfer to the soil via litter and root decay,
2. Nitrogen fixation by all leguminous trees and in few non-leguminous species (e.g., Alder and Casuarinas),
3. Improved nutrient retrieval by tree roots, including through mycorrhiza and from lower horizon,
4. Providing favourable conditions for the input of nutrients from rainfall and dust
5. Control of erosion by combination of cover and barrier effect, especially the former,
6. Root uptake of nutrients that would otherwise have been lost by leaching,
7. Soils under trees have favourable structure and water holding capacity, through organic matter maintenance and root action,
8. Provision of a range of qualities of plant litter, woody, and herbaceous,
9. Growth promoting substances,
10. The potential through management of pruning and relative synchronizatoion of timing of release to nutrients from litter with demand for their uptake by crops.

Control of soil erosion

On the basis of land capability classification, most of the hill sloppy lands of NEH are only suitable either for forestry or agroforestry. Soil erosion caused by runoff water on hill slopes without vegetative cover is the main cause of land degradation and ultimately resulting low productivity of soil. In the past the state governments have constructed terraces to settle the *jhumias*in isolation without further agricultural improvements. Very little success was achieved, many problems arose: the maintenance of soil fertility, excessive cost of the maintenance of mechanical structures, socially unacceptable to prohibit shifting cultivation (*jhum*) on sloppy lands, and compulsory means could not be forced (Patiram and Bhadauria, 1994). Erosion is now accepted as one of the main causes of soil degradation, including of physical, chemical and biological properties, all of which require attention. Mechanical means of soil erosion control measures are not cost effective and also cannot be well maintained; there is a greater interest in biological means of conservation. There is greater emphasis on the effects of soil cover as a means of controlling erosion, as compared with checking runoff. It is accepted that we cannot stop the cultivation on sloppy lands in this region. The inclusion of trees in soil conservation and erosion control is one of the most widely acclaimed and compelling reasons for including trees on farmlands prone to erosion hazards. The beneficial effects of trees in these regards extend beyond the immediate farmland under consideration, to impart stability to the ecosystem and reducing the rate of siltation of downstream aquatic system, dams and reservoirs.

Among the spatial zonal practices, the most effective means of erosion control is hedgerow intercropping or barrier hedges. The barrier hedges are contour aligned hedgerows planted specifically for erosion control on sloppy lands. It checks soil erosion through the cover effect, where hedge pruning are laid along cropped alleys. They reduce runoff, increase infiltration and reduce soil loss through their barrier effect. They maintain the soil organic matter through decay of pruning and root residues. In Mizoram, Thansanga (1997) developed the new contour farming system alternative to shifting cultivation involving planting of grasses preferably fodder with strong root formation at the lower edge of the trench line supported by various species preferably leguminous ones. The higher ridge of slope use for horticulture and forestry and contourfarming was practiced between the made contour trenching. It was found that whatever soil loss at the time of cultural operation get deposited in contour trench, and erosive crops like sweet potatoes, ginger etc. could safely be cultivated in this system without loss of top soil within the permissible soil loss (0.4 –15 t/ha). This system in time may replace the shifting cultivation by conserving soil and water to realize the paramount importance of permanent cultivation.

Dense ground forest vegetation (grass, cardamom, herbs, shrubs) under large cardamom plantation with shade trees on hill slopes more than 35% in Sikkim, arrests the flow of water, reduce the soil erosion and soil remains almost undisturbed (Patiram*et al.*, 1996). As a result large cardamom agroforestry resembles natural forest ecosystem.

Although the loss of runoff from highly sloppy lands of cardamom fields has been observed higher than the terraced field of maize crop, yet the loss of soil considerably reduced (Table 4). This result clearly revealed that even on such type of topography large cardamom with trees, the runoff contains almost clear water without suspended soil particle

Recycling of nutrients

The maintenance of soil fertility is much less a problem with treesthan with arable food-crops in addition to provide timber, fuel, fodder or other tree products,or shade. Competition and facilitation most often occur together. Trees may compete with acrop for light, leading to reduced crop yield through shading, whilst at the same timeincreasing soil organic matter and hence soil moisture content, and the availability ofnutrients for the crop through leaf litter. Nutrients enter the ecosystem with the rain, deposition of dust and aerosol, (in case of nitrogen) by fixation of microorganisms above andbelow ground, and weathering of the underlying rocks. The major above ground pool ofnutrients is the canopy and there is a flow of nutrients from this to the ground floor in smalland large litter fall and in trough fall and stem flow of rainwater, which usually becomesenriched by nutrients from leaves and bark (Anderson and Sinclair, 1993). Singh andRamakrishnan (1982) estimated the nutrient flow through incident rainfall, trough fall andstem flow through a 50 years stand of forest in sub-tropical humid climate of Meghalaya, andtotal amount of nutrients contributed given in Table 5. It can be seen from the table, the totalamount of nutrients (kg/ha/yr) through trough fall contributed 98% of all the nutrients,because of larger quantity of water passing through this compartment. More amounts of theCa and Mg contributed by trough fall as compared to N, P, and Mg.

As nutrient demand declines with age, gradual increase in nutrients in soil can occur as tree demands progressively fall below the rate of soil nutrient supply. The particular tree species adapted to particular soil conditions, the decomposition of litter leads with to the release of nutrients in a form available to plants; the rate of decomposition is controlled by climate and resource quality so that the efficiency of nutrient transfer will depend on the timing of release in relation to the maximum crop growth and plant nutrient demand. The Himalayan alder (*Alnus nepalensis*) is a native species of this hill region and has the immense importance in terms of rapid colonization on landslide-affected/prone sites. It stabilizes the steep slopes, nurse tree in age-old traditional cardamom plantations and agricultural field (jhum as well as terraced agriculture) in Nagaland. It has the capacity to fix substantial amount of atmospheric nitrogen, augments the soil fertility in both natural and its based agroforestry systems. Annual inputs of nutrients to the forest floor are mainly contributed by litter fall of leaf, twigs, catkins and residues left after under planted crops.

Soil physical properties

The water stability of soil aggregates is paramount in the restoration of soil structure to destructive forces. Structural stability increases with increasing organic matter content, which in turn is correlated with increased biotic activity. Soil microbial and megafaunal (earthworms) population improve water infiltration by altering soil physical structure. Bacteria produce thread-like polysaccharide adhesive and fungi produce thread-like hyphae that bind soil particles into stable aggregates and reduce potential soil losses by erosion (Gupta and Germida, 1988). The decaying tree roots, exudates, persistent of root channels, and root-associated fungi network also enhance the aggregate formation. The structural stability increases with increase in organic matter content, which in turn correlated with increased biotic activity. The lining of earthworm channels by slime, and of the root channels by mucigel, may make an important contribution to their stability and persistence (Oades, 1993).

Soil conservation

Soil erosion is one of the major causes of soil degradation on steeply sloping lands devoid of vegetative cover and often subjected to landslides or landslips during rainy season This process not only affects the land/soil but also cause loss of biodiversity including base resource itself, and human life. The loss of soil under shifting agriculture has been reported in the tune of 5 to 83 t/ha depending upon crops grown and slope of the land (Prasad et al., 1986). The loss of soil through runoff on such lands varied from 10.8 t/ha to as high as 62 t/ha depending upon land use for different types of agriculture (Prasad et al., 1986). The loss of topsoil reduces the inherent productivity of land through the loss of nutrients and degradation of the physical structure of the soil.

Conclusion

Soil enhancement under trees and agroforestry systems is largely attributable to increases in organic matter, either as surface litter or soil carbon. This article provided a description of several agroforestry systems utilized for soil conservation and soil health.In numerous agroecosystems, agroforestry systems play a crucial role in soil amelioration and enhancement of soil health. This paper suggests the assimilation and promotion of agroforestry practices, taking into account their multidimensional approaches to soil health and sustainable management.

Reference

Barbosa, R.I., Ferreira, E.J.G. and Castellón, E.G., 1997. *Homem, ambiente e ecologia no Estado de Roraima*. Inpa.

Bergo, C.L., Pacheco, E.P., Mendonça, H.A.D. and Marinho, J.T.D.S., 2006. Evaluation of legume species for coffee plants formation in the segment of family farms in Acre. *Acta Amazonica*, *36*, pp.19-24.

Bertin, C., Yang, X. and Weston, L.A., 2003. The role of root exudates and allelochemicals in the rhizosphere. *Plant and soil*, *256*, pp.67-83.

Doran, J.W., 1996. Soil health and sustainability. *Advances in Agron.*, *56*, pp.1-54.

Jose, S., 2009. Agroforestry for ecosystem services and environmental benefits: an overview. *Agroforestry systems*, *76*, pp.1-10.

Kleinman, P.J., Pimentel, D. and Bryant, R.B., 1995. The ecological sustainability of slash-and-burn agriculture. *Agriculture*, *Ecosystems & Environment*, *52*(2-3), pp.235-249.

Lavelle, P., Barros, E., Blanchart, E., Brown, G., Desjardins, T., Mariani, L. and Rossi, J.P., 2001. SOM management in the tropics: Why feeding the soil macrofauna?. In *Managing Organic Matter in Tropical Soils: Scope and Limitations: Proceedings of a Workshop organized by the Center for Development Research at the University of Bonn (ZEF Bonn)—Germany, 7–10 June, 1999* (pp. 53-61). Springer Netherlands.

Moreira, F.M., Siqueira, J.O. and Brussaard, L., 2008. *Biodiversidade do solo emecossistemasbrasileiros*. Universidade Federal de Lavras.

Nair, P.R., 1989. *Agroforestry systems in the tropics*. Kluwer Academic Publishers.

Nair, P.R., 2011. Agroforestry systems and environmental quality: introduction. *Journal of environmental quality*, *40*(3), pp.784-790.

Neves, E.G., Petersen, J.B., Bartone, R.N. and Augusto Da Silva, C., 2003. Historical and socio-cultural origins of Amazonian dark earth. *Amazonian Dark Earths: Origin Properties Management*, pp.29-50.

NRCS, U., 2018. Healthy soil for life. *Natural Rources Conservation Services Soils*.

Ramachandran Nair, P.K., Mohan Kumar, B. and Nair, V.D., 2009. Agroforestry as a strategy for carbon sequestration. *Journal of plant nutrition and soil science*, *172*(1), pp.10-23.

Ricklefs, R.E., 1996. Aeconomia da natureza. Guanabra Koogan.

Schroth, G., Lehmann, J., Rodrigues, M.R.L., Barros, E. and Macêdo, J.L., 2001. Plant-soil interactions in multistrata agroforestry in the humid tropicsa. *Agroforestry Systems*, *53*, pp.85-102.

Shah, P.B., 1996. Experience of soil fertility issues from Jhikhu Khola, a middle mountain watershed in Nepal. In *Formulating a strategy for soil fertility research in the hills of Nepal. Proceedings of a workshop held in Lumle Agricultural Research Centre, Pokhara, Nepal, 17-18 August 1995*. (pp. 109-113). Lumle Regional Agricultural Research Centre.

Takimoto, A., Nair, P.R. and Nair, V.D., 2008. Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. *Agriculture, ecosystems & environment*, *125*(1-4), pp.159-166.

Young, A. and International Council for Research in Agroforestry, 1989. Agroforestry for soil conservation.

Nair, P.R., Nair, V.D., Kumar, B.M. and Showalter, J.M., 2010. Carbon sequestration in agroforestry systems. *Advances in agronomy*, *108*, pp.237-307.

Grewia optiva: The wonder tree of the Himalayas

Saloni Rautela and Reena Joshi*

College of Forestry, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri, Uttarakhand 249199, India
*Email: joshireena14@gmail.com

Introduction

In the serene landscapes of the Himalayas, the Bhimal tree (*Grewia optiva*) also known as Dhaman or Beul, is a versatile gift of nature. This deciduous marvel graces the landscapes of Uttarakhand, Himachal Pradesh and beyond, thriving at altitudes ranging from 500 to 1800 meters. It reaches heights of 9 to 12 meters, having smooth, pale silvery-brown branches and ovate leaves that shimmer with life. From April to September, it adorns itself with clusters of small, fragrant yellow to red flowers, which give way to olive-green fruits that ripen to a rich black by December.Beyond its beauty, Bhimal offers a multitude of gifts to the communities it graces. Its fibrous bark is transformed into ropes, mats, and even natural shampoos, cherished for their purity and effectiveness. The leaves, rich in nutrients, serve as a vital fodder, especially during the winter months when other green feed is scarce. The fruits, with their pleasant acidic taste, are enjoyed fresh or used in local areas. Additionally, the tree's sturdy wood finds purpose in crafting tool handles and agricultural implements. Ecologically, Bhimal plays a pivotal role in soil conservation, its deep-root system anchoring the earth and preventing erosion.In essence, the Bhimal tree is not just a part of the landscape; it is a silent benefactor, nurturing both the environment and the communities that depend on it.

Utilization of *Grewia optiva*

Fodder source

One of the most crucial uses of *Grewia optiva* lies in its role as a high quality fodder, fuel and small timber. The leaves are highly palatable and rich in proteins. It provides fodder during winter months when no other green fodder is available. Leaves of this tree are excellent source of fodder in mid Himalayan region which retained appreciable amount of nutrients in leaves and therefore, it has been classified under good quality fodder trees. Its leaves contain 17.4-21% crude protein, 17-21.5% crude fiber, 10.4-21.5% total ash, 4.2-6% ether extracts and 40.4-50.2% nitrogen free extracts. Therefore, serves as a lifeline for livestock farmers. Its regular lopping does not harm the tree and ensures a sustainable supply of fodder, thereby supporting milk production and overall animal health. It provides an additional source of income generation through the sale of fodder, wood and fibre based handicrafts.

Fuelwood Source

The wood of *Grewia optiva* is an essential source of fuel for rural livelihoods and people living near the adjoining forest areas. It burns efficiently, provides steady heat, and is commonly used for cooking and heating purposes. Due to its rapid growth and coppicing ability, it ensures a continuous supply of fuelwood. This reduces dependency on forest resources and contributes to energy security in rural areas.

Fibre Production

The bark of *Grewia optiva* yields high quality bast fibres, which are traditionally used to make ropes, mats, bags, and other handicrafts. Additionally, it can be used in cottage industries and value added products. Therefore, in the rural livelihoods the people are generating a source of income through the value added products (Fig.1).

Fig.1: Handicrafts made from *Grewia optiva*fibresA and B-Baskets, C-Tray, D-Decorative article, E-Ropes and F-Wall hanging

Sustainable personal care products

It possesses natural properties that make it beneficial for use in shampoo formulations. Its extracts can help nourish the scalp, strengthen hair, and promote overall health. Incorporating *Grewia optiva* into shampoo, soap, scrub and face wash adds value to this multipurpose plant while supporting eco-friendly and sustainable personal care solutions (Fig. 2). It was seen that people are using the shampoo and other products in the rural areas and making a way for their source of income too. In many rural areas the bark and leaves are traditionally used as a natural shampoo. First the soft branches are collected from the tree of *Grewia optiva*. Then branches are peeled and soaked in water and rubbed between the palms until it gets soft and produces a foamy lather due to its natural saponins, then the extract is applied in the hairs, making the hairs smooth, shiny and silky. It is an eco-friendly, cost-free alternative to modern chemical shampoos reflecting the sustainable lifestyle of rural communities. Now at present, the processing, filtration, blending, formulations, packaging of Bhimal products is done and sent to the market for sale.

Fig.2: Personal care products made from*Grewia optiva*A-Soapand B-Shampoo

Soil Conservation

In the Himalayan states particularly in Uttarakhand, Bhimal is generally planted on slopes as a natural barrier for soil erosion, since its deep root system provides strong support and prevents soil from being washed away.

Retting of *Grewia optiva*: A Gentle Art of Fibre Extraction

The traditional water retting method unlocks the natural strength of *Grewia optiva*fibres with grace and minimal harm. This eco-friendly process takes 30-40 days with favorable climatic responses and has following steps (Fig.3):

Harvesting and Bundling

Mature branches are harvested by cutting selected branches without harming the tree, bundled for the retting process.

Retting

The harvested branches are submerged in running water for 30-40 days.

Agitation and Monitoring

The submerged branches are agitated regularly to ensure even exposure to microbial enzymes, enhancing retting uniformity and fibre release.

Fibre Extraction

Once softened, the fibres are extracted manually or beaten to free the fibers from the branches.

Separation &Washing

Fibres are thoroughly separated and washed to remove dirt and unwanted materials.

Drying

The fibre and branches are sun-dried to maintain hygiene and strength, yielding long, durable strands ideal for ropes, textiles and composites.

Bundling and storage

The clean fibreare bundled and stored for further use and applications.

After fibre extraction, the leftover woody core of branches (called as torchwood) is commonly used as fuelwood in rural households. Bhimalfibre is utilized to create a variety of articles including ropes, mats, baskets, brooms, and traditional eco-friendly handicrafts which support rural livelihoods and promote sustainable resource use.

Fig.3: Retting process of*Grewia optiva* (A-Bhimal tree, B-Bundles of Bhimal branches, C-Preparing site for retting process, D-Bhimalbranches submerged in water for 30-40 days, E and F-Cleaning and separation of fibre,G and H-Extracted wood andfibreare sun dried)

Challenges

Grewia optiva faces several challenges that hinder its utilization and management. A major issue is the lack of awareness among rural communities regarding its value addition potential. They are unaware that the raw materials can be processed and marketed in ways that significantly enhance their economic value. Processing, especially fibre extraction is inefficient, poor market access, and lack of value addition reduce its economic potential. Seasonal availability of leaves and branches also restricts its consistent use as fodder. Inadequate research support, weak extension services, and insufficient government policies or incentives contribute to itsunderutilization.

Way Forward

Looking a way forward to enhance the sustainable utilization of *Grewia optiva*, multipronged approach is essential. Raising awareness among farmers and rural communities about its economic and ecological benefits can promote its wider adoption. Strengthening market linkages and encouraging value addition through small scale industries can boost income generation. Introducing improved cultivation techniques, high-yielding varieties and efficient fibre extraction technologies and enhance productivity. Research and development should focus on its medicinal properties, soil conservation potential, climate resilience and community participation for sustainable planning of this valuable species.

Summary

Grewia optiva is a highly valuable multipurpose tree native to the sub-Himalayan region that contributes significantly to livestock nutrition, fodder andfuelwood supply, fibre production, soil conservation, fruit consumption and traditional medicine. The durablefibre extracted through the retting process is used to make handicrafts viz., baskets, mats, ropes, wall hanging and tray, which helps to generate income for rural livelihoods. Promoting its cultivation and value addition such as making shampoo, soaps and other sustainable personal care products aligns with the growing market for organic goods andcan significantly enhance rural livelihoods, helps in generating employment opportunities and foster sustainable land use in the Himalayan region.

Forests on the move: The silent ascent of trees due to changing climate

Nishma Dechamma T M and Venkatesh L

Department of Silviculture and Agroforestry
College of Forestry, Sirsi, Karnataka
E-mail: tmnishmadechamma@gmail.com, venkateshl@uasd.in

Abstract

Mountains are experiencing profound changes as rising global temperatures cause treeline shifting, where trees gradually expanding into higher altitudes. This shift reflects deeper climatic transformations, driven by warming, altered precipitation and reduced human pressure. In regions like the Indian Himalayas and European mountains, studies show significant upward treeline movement due to longer growing seasons and rising temperatures. These changes impact ecosystem structure, species composition, as well as services such as carbon storage, water regulation and soil stability. Tree encroachment into alpine zones displaces endemic flora and fauna, transforms nutrient cycles while reshaping microclimates and generates uncertainties in soil carbon dynamics alongside biodiversity resilience. Understanding treeline dynamics through ecological assessments is vital for conservation planning. Integrating community involvement and adaptive land-use practices are the key to managing the ecological impacts of this visible marker of climate change.

Keywords: Treeline, treeline shifting, tree encroachment, rising temperature

Introduction

Vegetation patterns are closely linked to climate, with tree distribution shaped by temperature, precipitation, solar radiation and soil. The treeline, marking the highest point where trees can survive, was once stable but is now shifting due to climate change. Rising temperatures are pushing treelines upward in mountains and poleward in higher latitudes. Though movement varies by region, the primary driver is global warming. This shift alters species composition, threatens alpine biodiversity, disrupts nutrient and carbon cycles and affects water regulation and soil stability. Treelines now serve as sensitive indicators of climate change and its ecological impacts. The trees are intruding the alpine grasslands and are modifying the habitat.

The shift around the world

Treeline shifting is driven by a complex interplay of biophysical, ecological and anthropogenic factors, with temperature as the most influential. Globally, the 10°C isotherm of the warmest month often defines treeline limits. Rising temperatures, longer growing seasons, reduced frost days, earlier snowmelt and lower snow cover enable tree establishment at higher elevations. However, precipitation dynamics also play a critical role. Changes in rainfall influence soil moisture and snowpack, affecting tree growth. For example, increased autumn precipitation in subarctic zones accelerates treeline advance, while moisture deficits and drought stress can inhibit it in temperate zones. Soil limitations—such as low nutrient availability, shallow depth, and permafrost and wind exposure—also restrict upward tree growth. Species traits (cold/drought tolerance, seed dispersal, competition, herbivory) influence migration success. Human activities like logging, grazing and fire suppression have historically altered treeline positions. In areas with reduced anthropogenic pressure, rapid natural recovery of treelines has occurred.

Evidence from the Indian Himalayas shows a 381 m vertical shift over four decades, with highest shifts in Arunachal Pradesh. Tree ring studies reveal species like Himalayan pine shifting variably due to microclimate and grazing. Some sites recorded 160 m/decade upward movement, others minimal change. In Europe, studies across 15 mountain ranges (Alps, Pyrenees, and Scandinavia) highlight roles of temperature, mountain size, latitude and human impact history, with 43% of variation in treeline attributed to these factors. Globally, the TREELIM model, based on data from 376 sites, accurately predicts treeline positions using climate parameters. A meta-analysis of 143 Northern Hemisphere sites shows 88% treeline advancement since 1901, with average shift of 0.354 m/year—faster in subarctic zones due to stronger warming and moisture. Ecological consequences include loss of endemic alpine species, biotic homogenization, altered carbon and nutrient cycles and changes in hydrology and slope stability. Forest encroachment increases above-ground biomass, but soil carbon effects remain uncertain. Shifts can also affect landslides, avalanches and water supply in mountain regions. Managing treeline impacts requires long-term monitoring (transects, dendrochronology, remote sensing), predictive modelling, soil restoration, climate-resilient species and community engagement. Policies must integrate treeline dynamics into climate adaptation and land-use planning for sustainable mountain ecosystem management.

Conclusion

Treeline shifting is a key indicator of climate change, reflecting altered temperature and moisture conditions in mountain ecosystems. This gradual movement of trees to higher altitudes impacts biodiversity, ecosystem functions and resilience. Recognizing treeline dynamics is vital for guiding conservation, forecasting and policy decisions. With effective monitoring and adaptive management, we can reduce negative impacts and support ecosystem stability in a warming world.

Reference

Chiu C A, C R Chiou, J R Lin, P H. Lin and C T Lin, 2014, Coldness index does not indicate the upper limit of evergreen broad-leaved forest on a subtropical island. *Journal of Forest Research*. 19:115–124.

Cudlín, P, Klopčič M, Tognetti R, Máliš F, Alados C L, Bebi P, Grunewald K, Zhiyanski M,

Andonowski V, La Porta N, BratanovaDoncheva S, Kachaunova E, Edwards Jonášová

M, Ninot J M, Rigling A, Hofgaard A, Hlásny T, Skalák P and Wielgolaski F E, 2017, Drivers of treeline shift in different European mountains. *Climate Research*, 73 (1 & 2): 135–150.

Hansson A, Dargusch P and Shulmeister J A, 2021, Review of modern treeline migration, the factors controlling it and the implications for carbon storage. *Journal of Mountain Science*, 18: 291–306.

Holtmeier, Friedrich Karl, 2009, Mountain timberlines, Ecology, patchiness and dynamics. *Advances in Global Change Research*, Vol. 36: 546-548.

Paulsen J and Körner C A, 2014, Climate-based model to predict potential treeline position around the globe. *Alpine Botany*, 124: 1–12.

Qi Zhao, Pei Yu, RahiniMahendran, Wenzhong Huang, Yuan Gao, Zhengyu Yang, Tingting Ye, Bo Wen, Yao Wu, Shanshan Li, YumingGuo, 2022, Global climate change and human health: Pathways and possible solutions. *Eco-Environment &Health*,Volume 1, Issue 2: 53-62.

Sandeep Kumar and Vinod Prasad Khanduri, Impact of climate change on the Himalayan alpine treeline vegetation. *Heliyon*, Volume 10, Issue 23: 2405-8440.

Singh C P, MohapatraJakesh, Mathew Jincy, KhurooAnzar, Hamid Maroof, Malik, Akhtar Khuroo, Rameez, Kumar Amit, VermaAnirudh, Nautiyal Mohan, Chandra Sudeep, Singh Ankit, S Subrat Naidu Swati, Shrestha Dhiren, Sharma Narpati, GajmerBandan, Tripathi O P, Ashish Bhattacharya and Bimal, 2021, Long-term observation and modelling on the distribution and patterns of alpine treeline ecotone in Indian Himalaya. *Journal of* Geomatics, 15: 68-84.

Surendra P Singh, A Bhattachary, A Mittal and Aseesh Pandey, 2021, Indian Himalayan Timberline Ecotone in Response to Climate Change – Initial Findings. *Current Science*, (5): 120.

Xiaoming L, Liang Eryuan, Wang Yafeng, BabstFlurin and CamareroJesús, 2021, Mountain treelines climb slowly despite rapid climate warming. *Global Ecology and Biogeography*, 30: 305-315.

Yadava K A, Yogesh K Sharma, Bhasha Dubey, Jayendra Singh, Vikram Singh, Mahendra R Bhutiyani, Ram R Yadav and Krishna G Misra, 2017, Altitudinal treeline dynamics of Himalayan pine in western Himalaya, *India Quaternary International*, 444: 44-52

महिलाओं की कृषि वानिकी में भूमिका: सशक्तिकरण एवं पर्यावरण संरक्षण

रोहिनी ठाकुर, आलोक कुमार सिंह*, बिपिन कुमार सिंह, रुपाली सिंह एवं अभिजित सिंह

राजीव गाँधी दक्षिणी परिसर, कशी हिन्दू विश्वविद्यालय मिर्ज़ापुर २३१००१
*ईमेल: alokkj63@bhu.ac.in

पृष्ठभूमि

कृषि वानिकी की मूल अवधारणा लकड़ी के बारहमासी पौधों (जैसे पेड़, झाड़ियाँ, ताड़, बाँस, आदि) को कृषि फसलों और/या पशुओं को समान भूमि-प्रबंधन इकाइयों पर योजनानुसार एकीकृत करना है। यह एक प्रथा है जिसमें पेड़ों, फसलों और कभी-कभी पशुओं को एक ही भूमि उपयोग

चित्र १: कृषि वानिकी प्रणाली में महिलाओं के योगदान को दर्शाता दृश्य

प्रणाली में योजनानुसार एकीकृत किया जाता है। फसलों और/या पशुओं के साथ पेड़ों को एक-दूसरे के साथ जोड़ने या जानबूझकर बनाए रखने से एक ही प्रणाली से कई उत्पादों या लाभों को प्राप्त करने में मदद मिलती है। कृषि वानिकी से यह बहुविध उत्पादन न केवल भूमि उत्पादकता को बढ़ाता है, बल्कि जैव विविधता के संरक्षण, कार्बन पृथक्करण, और जलवायु परिवर्तन के शमन और अनुकूलन में भी मदद करता है। ग्रामीण क्षेत्रों में महिलाओं को अक्सर विभिन्न कृषि कार्यों और प्राकृतिक संसाधन प्रबंधन के लिए रीढ़ की हड्डी माना जाता है। ग्रामीण घरों में महिलाएँ खाद्य उत्पादन, जलाऊ लकड़ी संग्रह, पारिस्थितिकी तंत्र को बनाए रखने और घरेलू संसाधनों के प्रबंधन जैसी गतिविधियों में महत्वपूर्ण भूमिका निभाती हैं, फिर भी उन्हें अक्सर विभिन्न भूमि, प्रौद्योगिकी, ऋण और शिक्षा तक पहुँचने में बाधाओं का सामना करना पड़ता है। ग्रामीण कृषि प्रणाली में महिलाएँ अक्सर पेड़ों के प्रबंधन और अन्य कृषि उद्यमों के लिए जिम्मेदार होती हैं। विभिन्न कृषि वानिकी अभ्यास उनकी सामाजिक आर्थिक स्थिति को बदलने और पर्यावरण स्थिरता को बढ़ावा देने में मदद कर सकते हैं। जब महिलाएँ कृषि वानिकी अभ्यासों में संलग्न होती हैं, तो उन्हें कई प्रकार के उत्पादन करके अपने आय स्रोतों में विविधता लाने का अवसर मिलता है, जो परिवार को आर्थिक रूप से मजबूत बनाने और विभिन्न प्रकार की फसल और वृक्ष उत्पादों की खेती करके खाद्य सुरक्षा और पोषण को बढ़ाने में मदद करेगा। यह भागीदारी न केवल उनके परिवार की आय में विविधता लाती है, बल्कि स्वस्थ आहार को बढ़ावा देने और उनके परिवारों के सुरक्षित भविष्य में भी मदद करती है। साथ ही कृषि वानिकी एक कम लागत वाली प्रणाली है, जिसमें न्यूनतम लागत की आवश्यकता होती है और यह चारा, भोजन, लकड़ी, फल और मिट्टी की उर्वरता में सुधार जैसे उत्पादों और सेवाओं की विविधता प्रदान करती है। कई पेड़ों को नकद निवेश की आवश्यकता नहीं होती है या केवल बीज या पौध की खरीद के लिए न्यूनतम राशि की आवश्यकता होती है। यह उन महिलाओं को अपार अवसर प्रदान करता है, जो अधिकांश मामलों में अपनी गंभीर नकदी और ऋण बाधाओं के कारण उच्च लागत वाली तकनीकों को अपनाने का

जोखिम नहीं उठा सकती हैं। कृषि क्षेत्र में उनकी महत्वपूर्ण भूमिका के बावजूद, विभिन्न सामाजिक सांस्कृतिक और आर्थिक बाधाओं के कारण महिलाओं की भूमिका को अक्सर अनदेखा किया जाता है। इन विभिन्न कारकों में सांस्कृतिक मानदंड, लिंग भूमिकाएं, निर्णय लेने में प्रतिनिधित्व की कमी, संसाधनों तक सीमित पहुंच, अवैतनिक श्रम की अदृश्यता, सामाजिक-आर्थिक बाधाएं और विभिन्न नीतिगत और संस्थागत बाधाएं शामिल हैं। कृषि वानिकी से जुड़े विभिन्न कारकों में भूमि स्वामित्व का मुद्दा, श्रम की कमी, अपर्याप्त विस्तार जानकारी, ज्ञान और कौशल की कमी शामिल है।

कृषि वानिकी में महिलाओं की भूमिका: मिथक और वास्तविकता

वानिकी और कृषि वानिकी क्षेत्र को अक्सर पुरुष प्रधान क्षेत्र माना जाता है। परंपरागत रूप से महिलाएं विभिन्न कृषि और वृक्ष प्रबंधन प्रथाओं में महत्वपूर्ण भूमिका निभा रही हैं, हालांकि विभिन्न सामाजिक और सांस्कृतिक मानदंडों के कारण उनकी भूमिका को अक्सर अनदेखा कर दिया जाता है। महिलाएं अक्सर ऐसी गतिविधियों में शामिल होती हैं जिन्हें शारीरिक रूप से कम वाला माना जाता है। कृषि वानिकी प्रथाओं और संसाधनों से संबंधित निर्णय लेने में उनकी भूमिका बहुत कम होती है। अपनी महत्वपूर्ण भूमिका के बावजूद, महिलाओं को आवश्यक संसाधनों तक पहुंच में असमानताओं का सामना करना पड़ता है,कई प्रचलित धारणाएं और मिथक हैं जो महिलाओं के महत्वपूर्ण योगदान को अनदेखा कर देते हैं। सबसे प्रचलित मिथकों में से एक यह है कि महिलाएं केवल गृहिणी होती हैं जो सच नहीं है। एक छोटे से ग्रामीण घर में महिलाएं सभी प्रमुख खाद्य उत्पादन गतिविधियां करती हैं महिलाएँ पशुपालन में भी शामिल होती हैं, जैसे की गाय और विभिन्न दूध देने वाले जानवर। इस प्रकार कृषि वानिकी में चारे के पेड़ का उत्पादन घर की चारे की आवश्यकता को पूरा करने में महत्वपूर्ण रूप से मदद कर सकता है। महिलाओं के बारे में दूसरा मिथक यह है कि वे समुदाय के एक निष्क्रिय सदस्य के रूप में कार्य करती हैं। यह धारणा मुख्य रूप से इसलिए पैदा होती है क्योंकि विभिन्न सांस्कृतिक मानदंडों के अनुसार महिलाओं को अक्सर घरेलू भूमिकाओं से जोड़ा जाता है, जिससे समाज में उनके महत्वपूर्ण योगदान की अनदेखी होती है। कई समाजों में महिलाओं को अक्सर गृहिणी की उनकी पारंपरिक भूमिका से जोड़ा जाता है, जबकि भूमि प्रबंधन, जैव विविधता पर बातचीत और नृजातीय वनस्पति ज्ञान में उनके कौशल को मान्यता नहीं दी जाती है। महिलाओं का सार्वजनिक क्षेत्र पर भी बहुत प्रभाव है। खेजड़ी आंदोलन अहिंसक पर्यावरण आंदोलन है जिसका नेतृत्व अमृता देवी बिश्नोई नामक महिला ने किया था महिलाओं से जुड़ा चौथा मिथक यह है कि वन उत्पाद और संसाधन पुरुषों के अधिकार क्षेत्र में आते हैं, जबकि सच यह है कि ग्रामीण इलाकों में आमतौर पर महिलाएं ईंधन की लकड़ी, विभिन्न गैर-लकड़ी वन उत्पादों (जैसे गोंद, राल, रेशा, आवश्यक तेल, तेंदु के पत्ते आदि) और औषधीय पौधों के संग्रह से जुड़ी होती हैं। महिलाएं परिवार की जरूरतों और इच्छाओं के बारे में अधिक जागरूक होती हैं। महिलाओं को आमतौर पर क्षेत्र की जैव विविधता और संसाधन समृद्धि के बारे में व्यापक जानकारी होती है। इसके विपरीत पुरुष वन उत्पादों के संग्रह और बिक्री के बजाय वाणिज्यिक वानिकी में अधिक रुचि रखते हैं।

कृषि वानिकी की सहायता से महिलाओं का सशक्तिकरण

कृषि वानिकी महिला सशक्तिकरण, टिकाऊ कृषि, विविध आय, और टिकाऊ खाद्य स्रोतों के लिए एक अनूठा अवसर प्रदान करती है। खेत पर पेड़ों

की प्रजातियों के लिए नेतृत्व और निर्णय लेने की प्राथमिकता के संदर्भ में महिलाओं की महत्वपूर्ण भूमिका है। विभिन्न तरीके जिनसे कृषि वानिकी महिला सशक्तिकरण में मदद करती है:

आय विविधीकरण और वित्तीय स्वतंत्रता

कृषि वानिकी फल, भोजन, सब्जियां, लकड़ी, चारा और अन्य गैर-लकड़ी वन उत्पादों जैसे कई उत्पाद प्रदान करती है; ये विविध उत्पाद महिलाओं के लिए आय का एक विविध और स्थिर स्रोत प्रदान करने में मदद करते हैं। दुनिया के विभिन्न हिस्सों में दूध उत्पादन ग्रामीण महिलाओं के लिए आय का एक प्रमुख स्रोत है। चारे की कमी और चारे की खराब गुणवत्ता पशुधन उत्पादकता और प्रजनन प्रदर्शन को बेहतर बनाने में सबसे बड़ी बाधा है, खासकर शुष्क मौसम के दौरान। यहाँ कृषि वानिकी की एक वन चरागाह तंत्र प्रणाली है जिसमें एक ही एकड़ में लकड़ी, पशुधन और चारा उत्पादन का संयोजन शामिल है। यहाँ प्रोटीन से भरपूर पेड़ और चारा घास उगाई जाती है जो चारे की गुणवत्ता में सुधार करती है। पेड़ दीर्घकालिक लाभ प्रदान करते हैं, जबकि पशुधन और चारा वार्षिक आय उत्पन्न करते हैं। इस प्रकार, चारे की प्रजातियाँ महिलाओं को बकरियों या मवेशियों जैसे पशुधन को पालने में मदद कर सकती हैं। साथ ही, पेड़ एकल भूमि प्रबंधन इकाई से लकड़ी या ईंधन की लकड़ी का उत्पादन करने में मदद करते हैं। ये प्रणालियाँ महिलाओं के दूर के जंगलों से चारा इकट्ठा करने में खर्च होने वाले समय और ऊर्जा को कम करती हैं, जिससे उनकी उत्पादकता और कमाई की क्षमता बढ़ती है।

नए उत्पादों का नवाचार

महिलाएं अपनी कृषि फसलों के साथ-साथ स्थानीय बाजारों के लिए कच्चे और संसाधित माल का प्रभावी ढंग से उत्पादन कर सकती हैं। वे नए उत्पाद विकसित करने के अवसर तलाश सकती हैं। महिलाओं के लिए प्रतिस्पर्धा में अनुकूलता के लिए, उनके पास बढ़त है, क्योंकि वे आमतौर पर पारंपरिक उत्पादों के बारे में अच्छी तरह से जानती हैं जिन्हें तेल, साबुन, जूस, बॉडी लोशन, वाइन और पत्ती के भोजन जैसे उच्च मूल्य वाले उत्पादों की विविधता में परिवर्तित किया जा सकता है। हालांकि, जोखिम, लाभप्रदता, प्रतिस्पर्धा और पैमाने की अर्थव्यवस्थाओं का ध्यान रखते हुए, ऐसे नए उत्पादों का सावधानीपूर्वक मूल्यांकन करने की आवश्यकता है। इस उत्पादन से महिलाओं की आर्थिक स्थिति में सुधार हो सकता है और छोटे कुटीर उद्योग भी स्थापित किए जा सकते हैं।

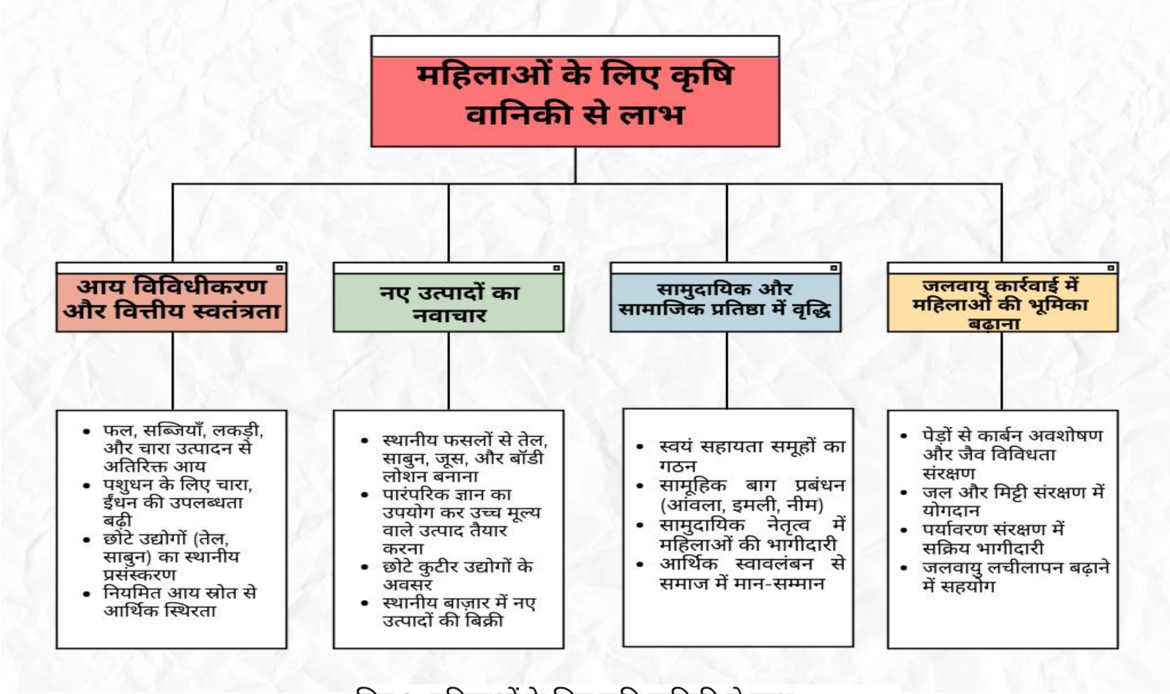
सामुदायिक और सामाजिक प्रतिष्ठा में वृद्धि

सामुदायिक कृषि वानिकी प्रणालियों में, महिलाएं सामूहिक रूप से कई स्वयं सहायता समूह बना सकती हैं। वे उच्च मूल्य वाले फलों या बिना लकड़ी उत्पाद वाले पेड़ों जैसे आंवला (भारतीय करौदा), इमली और नीम के विभिन्न बागों का प्रबंधन कर सकती हैं। ये समुदाय संचालित परियोजनाएँ महिलाओं के आर्थिक उत्थान में मदद करती हैं और उन्हें एक साथ काम करने, अनुभव, संसाधन, विचार साझा करने और विभिन्न सहायता नेटवर्क बनाने के लिए एक स्थान प्रदान करती हैं, जो चुनौतियों के प्रति लचीलापन बढ़ाती हैं। ये समुदाय महिलाओं की दृश्यता और सामाजिक भूमिका को उजागर करने में मदद कर सकते हैं, क्योंकि वे समुदाय के सार्वजनिक और सामाजिक क्षेत्र में अधिक दिखाई देती हैं। महिलाएँ ऐसे संकेतकों के माध्यम से आर्थिक स्वतंत्रता भी प्राप्त कर सकती हैं और इस प्रकार वे अब वित्तीय सुरक्षा के लिए केवल पुरुष परिवार के सदस्यों पर निर्भर नहीं हैं।

जलवायु कारवाही में महिलाओं की भूमिका बढ़ाना

कृषि वानिकी जलवायु परिवर्तन शमन और पर्यावरण संरक्षण के लिए एक महत्वपूर्ण उपकरण

के रूप में कार्य करती है। पेड़ मिट्टी और जल संरक्षण के लिए एक स्रोत के रूप में कार्य करते हैं। पेड़ों का कार्बन अवशोषण और जैव विविधता के संरक्षण में महत्वपूर्ण भूमिका होती है। कृषि वानिकी में महिलाओं के योगदान से स्थानीय जलवायु लचीलापन और जलवायु परिवर्तन शमन में सहायता मिलती है। चूंकि महिलाएं विभिन्न पेड़ों की देखभाल करती हैं, इसलिए वे पर्यावरण के संरक्षण में भी मदद करती हैं और पर्यावरण संरक्षक के रूप में सम्मान और मान्यता प्राप्त कर सकती हैं।



चित्र २: महिलाओं के लिए कृषि वानिकी से लाभ

इसलिए, यह निष्कर्ष निकाला जा सकता है कि कृषि वानिकी ईंधन की लकड़ी और चारे की उपलब्धता को बढ़ाने में मदद करती है, जो उनके संग्रह में समय की बर्बादी को कम करने में सहायक होती है। इसके अलावा, कृषि वानिकी में महिलाओं की भागीदारी उनके नेतृत्व कौशल, आत्मविश्वास और सकारात्मक विशेषताओं को विकसित करने में मदद करती है। विविध आय स्रोत उन्हें आर्थिक स्वतंत्रता प्राप्त करने में मदद करते हैं। विभिन्न स्वयं सहायता समूहों और सहकारी समितियों के गठन से भी उनकी सरकारी योजनाओं और संकेतकों तक पहुँचने में मदद मिलती है।

स्थिति अध्ययन

यह स्थिति अध्ययन भारत के बुंदेलखंड क्षेत्र में कृषि वानिकी प्रणाली के प्रभावों की जांच करती है। बुंदेलखंड मध्य भारत का एक अर्ध शुष्क क्षेत्र है, जहां महिलाएं पारंपरिक लिंग विशिष्ट भूमिकाओं में जैसे पशुओं को चारा खिलाना, ईंधन की लकड़ी इकट्ठा करना, पीने के पानी की व्यवस्था करना, और विभिन्न अन्य घरेलू कामों में लगी हुई थीं। ये समय लेने वाली और गहन श्रम वाली गतिविधियाँ थी, जो आय पैदा करने वाली गतिविधियों में संलग्न होने की उनकी क्षमता को सीमित करती थीं।

इन चुनौतियों के समाधान के लिए, आईसीएआर-केंद्रीय कृषि वानिकी अनुसंधान संस्थान (CAFRI) ने महिलाओं की भूमिकाओं को बढ़ाने के लिए एक भागीदारी कृषि वानिकी परियोजना

शुरू की। इस परियोजना ने वाटरशेड-आधारित कृषि वानिकी प्रणाली (जिसमें जल संचयन को बढ़ावा दिया जाता है) के साथ एक व्यावहारिक समाधान पेश किया। परियोजना के अंतर्गत वर्षा जल संचयन के लिए चेक डैम बनाये गये और वैज्ञानिकों ने निःशुल्क पौधे, तकनीकी मार्गदर्शन और प्रेरणा भी प्रदान की, जिससे महिलाओं को जलग्रहण क्षेत्र और घर के आसपास फलदार वृक्ष, घास और सब्जियाँ लगाने के लिए प्रोत्साहित किया गया।

इसके परिणामस्वरूप, जैसे-जैसे अधिक महिलाएँ इन उद्यानों को लगाने और उनकी देखभाल करने में आत्मविश्वासी होती गईं, पूरे गाँव में घर के आंगन के बगीचों का एक समृद्ध नेटवर्क उभर कर आया, जो परिवार की के लिए पौष्टिक फल और सब्जियाँ पैदा करता था। इस प्रकार, बाजार से भोजन खरीदने के बजाय, महिलाओं ने अपनी ज़रूरत की चीज़ें उगाईं, जिससे उनके परिवार को ताज़ी, स्वस्थ उपज मिली।

लड़कों को खेत, लड़कियों को मेड़, और हर मेड़ पर 100 सागौन के पेड़ का नारा समुदाय में बहुत ज़ोरदार तरीके से गूंज उठा। इस संदेश ने कई महिलाओं को कृषि वानिकी पद्धतियों को अपनाने के लिए प्रेरित किया, जो अपनी बेटियों के भविष्य के लिए सागौन की लकड़ी से होने वाली संभावित आय से प्रेरित थीं। इस मॉडल ने महिलाओं को भूमि उपयोग के बारे में निर्णय लेने, इन कृषि वानिकी वृक्षारोपणों के लिए स्वामित्व और जिम्मेदारी की भावना को बढ़ावा देने के लिए सशक्त बनाया है। बुंदेलखंड में आईसीएआर-सीएएफआरआई द्वारा संचालित पहल यह दर्शाती है कि कृषि वानिकी के माध्यम से महिलाओं को सशक्त बनाने से जीवन की गुणवत्ता में उल्लेखनीय सुधार हो सकता है, लैंगिक समानता को बढ़ावा मिल सकता है, तथा अधिक टिकाऊ, लचीले ग्रामीण समाज की नींव रखी जा सकती है।

Unlocking the potential of Bael: Addressing pests, diseases, and physiological disorders

Shailendra Bhalawe, Dhananjay Kathal and Uttam Bisen

Department of Forestry
College of Agriculture Balaghat
Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur (M.P.)
Email: sbhalawe@gmail.com

Abstract

Bael (*Aegle marmelos* Correa), commonly known as a "wonder tree," is a hardy and underutilized fruit crop predominantly grown in semi-arid regions. Despite its rugged appearance and seeming resistance to biotic stress, bael is in fact susceptible to a range of diseases and pests. Common diseases affecting bael include gummosis, fruit rot, anthracnose, and various leaf spot diseases. The tree is also prone to pest attacks from lemon butterflies (*Papilio demoleus*), leaf miners, and termites, all of which can lead to significant damage and yield reduction if left unmanaged. In addition to these biotic stresses, bael also suffers from several physiological disorders, which are caused by environmental and nutritional imbalances rather than pathogens. Notable disorders include fruit cracking, premature fruit drop, and sun scalding. These issues negatively affect fruit texture, marketability, and overall yield, posing serious challenges to commercial cultivation. To address these challenges, a combination of simple yet effective management practices can be employed. Regular monitoring is essential for early detection of pests and diseases. Judicious use of organic and chemical controls can help manage infestations and infections. Proper irrigation and balanced fertilization, especially with micronutrients such as calcium and boron, play a critical role in preventing physiological disorders. Additionally, techniques like mulching and providing shade during peak summer months can reduce heat stress, while regular pruning and sanitation improve air circulation and reduce disease incidence. By implementing these integrated management strategies, farmers can improve plant health, minimize losses, and enhance the sustainable cultivation of this valuable yet often overlooked fruit crop.

Keywords: Bael, Physiology, Shrinked, Disease, Pest

Introduction

Bael (*Aegle marmelos* Correa), a deciduous and underutilized fruit tree of significant agro-horticultural and medicinal value, typically grows to a height of 6–10 meters and is distinguished by its axillary thorns and aromatic trifoliate leaves. The fruit, generally oblong to pyriform in shape, develops slowly, requiring nearly a year to reach full maturity. Native to the Indian subcontinent, bael is well adapted to semi-arid and subtropical climates and is naturally distributed across the Indian Peninsula, extending up to 1,200 meters in the Western Himalayas. It thrives particularly well in the states of Uttar Pradesh, Bihar, Chhattisgarh, Uttarakhand, Jharkhand, and Madhya Pradesh. Optimal conditions for bael cultivation include well-drained sandy loam soils, full sunlight, and a warm, humid climate. During early stages of development, bael fruits are deep green in color, gradually turning light yellow as they ripen. Harvesting is typically carried out between mid-April and May, and ripe fruits are easily identified as they detach naturally when plucked with a small portion (about 1 cm) of the fruiting stalk. On average, a mature bael tree yields 300–400 fruits annually. However, it has been observed that fruits with larger and heavier seed sacs tend to contain excessive mucilage, which adversely affects overall fruit quality. Careful timing and method of harvest are therefore critical to maintaining the desired fruit characteristics. In addition to its horticultural potential, bael holds immense therapeutic significance. It is widely recognized for its exceptional nutraceutical and medicinal properties, exhibiting a broad spectrum of biological activities such as anticancer, antidiabetic, antimicrobial, anti-inflammatory, antipyretic, analgesic, cardioprotective, anti-spermatogenic, and radioprotective effects. These qualities make bael not only an important crop for sustainable agriculture but also a valuable resource for the development of functional foods and herbal medicines. With proper agronomic management and increased awareness, bael can play a vital role in enhancing rural livelihoods and promoting health-oriented crop diversification. A newly emerging physiological disorder, characterized by the shrinkage of bael fruits—particularly in the cultivar Bael has recently been reported in the subtropical regions of India. This disorder is believed to stem from complex physiological imbalances, primarily involving inadequate soil moisture, limited water availability, and restricted assimilate translocation to the developing fruits. These issues are often associated with adjoining senescent branches or drying twigs. The incidence is notably high during the dry, sunny months of February and March, when increased evapotranspiration accelerates water loss from the fruit surface. The disorder is closely linked to reduced leaf water potential and is commonly observed in portions of the canopy where twig desiccation follows the senescence of photosynthetically active leaves. Simultaneously, xylem vessels in the affected twigs may become clogged, further impeding the upward movement of water and minerals to the fruit—the primary sink tissue—ultimately resulting in fruit dehydration and shrinkage.

Physiological Impairments in Bael Trees Exhibiting Fruit Shrinkage

India is home to a rich genetic diversity of bael (*Aegle marmelos*) trees, many of which possess high yield potential and remarkable nutritional value. In recent years, significant advancements in bael varietal improvement have been made by research institutions. The ICAR-Central Institute for Subtropical Horticulture (CISH), Lucknow, has developed two notable cultivars—CISH B-1, a mid-season maturing variety producing fruits weighing up to 1.0 kg, and “CISH B-2’, a dwarf variety with a moderate canopy spread, producing large fruits ranging from 1.8 to 2.7 kg, characterized by low fibre and seed content. Similarly, the Central

Horticultural Experiment Station, Godhra (Gujarat), introduced “Goma Yashi”, a dwarf and spineless variety known for its prolific bearing and early maturity. G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), has also contributed several superior cultivars: “Pant Aparna” (a dwarf, nearly thornless variety with drooping flowers, early bearing, and high productivity), “Pant Shivani” (an early bearer), “Pant Sujata” (a medium dwarf with drooping and spreading foliage), and “Pant Urvashi” (a mid-season, precocious, and heavy bearer). Despite these advancements, the recently observed phenomenon of fruit shrinkage—particularly some cultivars has raised concern among researchers and growers. Physiological assessments have revealed that branches affected by fruit shrinkage exhibit significantly lower photosynthetic rates (4.8 μmol m^{-2} s^{-1}) and stomatal conductance (214 mmol m^{-2} s^{-1}) compared to healthy branches, which record 6.5 μmol m^{-2} s^{-1} and 371 mmol m^{-2} s^{-1} respectively. Moreover, the water use efficiency (WUE: A/E) of the affected twigs was found to be halved—only 0.7 in contrast to 1.5 in healthy ones—indicating severe physiological stress. It is hypothesized that abscisic acid levels may be elevated in the peduncle of affected fruits, as the shrinked fruits tend to abscise readily upon slight physical contact. These findings suggest that hormonal imbalance, coupled with impaired water relations and reduced gas exchange, may play a critical role in the development of this disorder.

Physiological Challenges in Bael Production: Causes and Management

Bael (*Aegle marmelos*), though considered a hardy fruit tree, is increasingly facing multiple physiological disorders that are becoming significant barriers to quality fruit production—especially in the context of changing climate conditions. These disorders are primarily induced by extreme temperatures, poor moisture regimes, unbalanced soil nutrition, deficiencies or toxicities of specific soil minerals, improper soil pH, and inadequate drainage. Among the major physiological issues observed, fruit cracking is particularly common and occurs in two distinct phases: first during December–January, when the fruits are immature and still developing, and again during March–April, when the fruits are mature and entering the ripening phase. This disorder is typically triggered by fluctuations in soil moisture and temperature. Effective management includes maintaining an optimum moisture regime through organic mulching and establishing windbreaks around the orchard. Another prevalent disorder is fruit drop, which, while partly a natural phenomenon, can be significantly reduced through organic mulching and foliar application of NAA (Naphthalene Acetic Acid) at 15–20 ppm during the pea-sized fruit stage in August–September. Sun scald is also frequently observed, particularly on the fruit shell, where exposure to intense solar radiation—combined with inadequate soil moisture—results in the transformation of the green shell to a dark brown color. Although the internal pulp remains largely unaffected, the elevated temperature (8–10°C higher than the unexposed portion) in the scorched area diminishes fruit appearance and thereby lowers its market value. Canopy management and mulching have proven effective in reducing the severity of sun scald to some extent. To manage these physiological disorders more holistically, foliar applications of borax (0.1%) twice—once at full bloom and again after fruit set—are recommended, along with the use of NAA at 20–30 ppm, particularly in subtropical regions. Consistent maintenance of soil moisture near the rhizosphere is also crucial in mitigating stress. In addition to the above challenges, a newly emerging physiological disorder—fruit shrinkage—has recently been reported in bael, particularly at the full developmental stage of the fruit. The disorder not only impairs fruit appearance but also leads to a significant reduction in yield, adding further concern for growers. The emerging nature of this malady, alongside existing physiological stressors, underscores the urgent need for integrated orchard management and adaptive practices to ensure sustained bael production under variable climatic conditions.

Seasonal Occurrence of Shrinkage Disorder in Bael Fruits

The phenomenon of fruit shrinkage in bael is primarily observed during the months of January and February, coinciding with low night temperatures—often dropping below 11°C. This disorder is most prominently seen in the various variety, where more than 30% of the trees have shown symptoms. The intensity in those cases remains relatively low, affecting less than 10% of the planted trees. In some instances, fruits that are infected late in their development undergo severe shrinkage, turn black, become extremely light in weight, and take on a mummified appearance. These affected fruits often remain attached to the tree by their stalks for an extended period, further indicating the persistence and severity of the disorder in certain cases.

Underlying Causes of Fruit Shrinkage in Bael

The recently emerging disorder of fruit shrinkage in bael, particularly in the widely cultivated variety, appears to be primarily driven by physiological stress in fruit-bearing branches. The most likely cause is the disruption of water and assimilate transport, often due to xylem blockage in twigs affected by cold stress or frost injury. These symptoms are typically observed in branches where leaves and shoots undergo complete senescence following winter, resulting in impaired vascular function. Fruit shrinkage is further exacerbated by diurnal fluctuations in atmospheric conditions, where expansion and contraction of fruits correlate with water deficit stress. During the months of January and February, night temperatures ranging between 3.9°C and 10.1°C under clear skies were recorded—conditions conducive to frost formation and physiological injury. This disorder has reached an alarming prevalence and affecting over 30% of trees in certain orchards, thereby causing significant economic losses due to reduced fruit quality and marketability. Given the popularity of some cultivated variety for its high yield potential, soft pulp, low mucilage, and overall consumer preference, addressing this malady is critical. A targeted breeding programme should be initiated to enhance abiotic stress tolerance without compromising its superior fruit traits. Simultaneously, the development of integrated crop management (ICM) strategies—including frost mitigation measures, optimized irrigation scheduling, nutrient balancing, and improved canopy management—is essential for sustainable bael production. Establishing bael-based cropping systems could also offer income stability and climate resilience to farmers in northern India, ensuring the continued viability of this valuable cultivar under evolving climatic conditions.

Geotourism championing the environmental practices

S. Jayasri, P. Kalaivani, S. Keshavarthini* and P. Kanishka

Forest College and Research Institute, Tamil Nadu Agricultural University
Mettupalayam – 641 305, Coimbatore (Dt), Tamil Nadu
*E-mail: keshavarthini954@gmail.com

Geo-tourism, an arising form of sustainable tourism, focuses on the geological features of a particular region with environmental concern. This type of tourism has the ability to raise environmental consciousness, preserve natural heritage and engage communities, making it a novel field of study.

With its emphasis on a location's geology and cultural legacy, geo-tourism has the potential to be a potent instrument for environmental preservation. It encourages eco-friendly travel methods that protect the environment, include the community, and cultivate respect for the region's geological and cultural legacy. Destinations may preserve their distinctive landscapes, while benefiting local people economically and educationally by combining geo-tourism with ecotourism concepts. Here's how Geo -tourism contributes to reserve the environmental protection through

- To educate tourists about the geological features of a particular spot.
- To preserve the geologically significant landscapes.
- To facilitate cultural exchange between tourists and local communities.
- To support geo-conservation efforts and protect geological features from degradation.
- To involve local communities in geo-tourism development and management.
- To generate income and benefits for local communities.
- To Support research and monitoring of geological features and sites.

Geotourism sites in India

India is well-known for its variety of geological features with nearly 40 notified geo-tourism sites in India. Few of the geo-tourism sites are

Geotourism Sites	Location
Ajanta Caves & Ellora Caves	Maharashtra
Akal Fossil Wood Park	Rajasthan
Arwah-Lumshynna Caves	Meghalaya
Barr Conglomerate	Rajasthan
Dhala Impact Structure	Madhya Pradesh
Eparchaean unconformity/natural arch	Andhra Pradesh
Fossils of Raajmahal hills	Jharkhand
Kerala Backwaters	Kerala
Marine Gondwana Fossil Park	Chattisgarh
Naga hill Ophiolite	Nagaland
Peninsular Gneisses	Karnataka
Salkhan Fossil Park	Uttar Pradesh
Sattanur Fossil Wood Park	Tamil Nadu
SeLa Pass	Arunachal Pradesh

Shiwalik Fossil Park	Himachal Pradesh
Stromatolite bearing Carbonate	Sikkim
Sundarban- The Mangrove Forest	West Bengal
Thiruvakkarai Fossil Wood Park	Tamil Nadu

Geo-tourism sites with environmental concern

A) Sundarban - The Mangrove Forest

The Sundarban, which includes the Sundarban mangrove forest and the impact zone that surrounds it, is significant locally and globally because of the ecosystem's richness, diversity, and distinctiveness. As the world's largest mangrove forest, it has drawn interest from researchers, environmentalists, and nature enthusiasts worldwide. It was designated a Ramsar Site of International Importance in 1992 and a Natural World Heritage Site by UNESCO in 1997.

The 102 islands that make up the Sundarbans are home to a remarkable ancient legacy of mythological and historical events, as well as abundant natural resources of geological, anthropological, and archaeological significance, as well as a diverse range of mangrove flora and fauna. The Sundarban delta is situated in southeast India and southwest Bangladesh in the lower Ganga River basin.

Threats to Biodiversity in Sundarbans Geo-site

- Anthropogenic impacts like reclamation, human encroachment and influence.
- Geomorphic stress caused by the neo-tectonic tilting of the Bengal basin.
- Recurrent coastal cyclone/ storm surge events, flooding issues related to climate change (global warming), changes in relative sea level rise.
- Checking up upland/hinterland flow of the rivers, huge silt deposition and high salinity and acidity problem, loss of soil fertility, coastal erosion.
- Expansion of aquaculture in the forest fringe area.
- Extension of other non-forestry land use into mangrove forest and effect of agricultural chemical.
- Poaching of tiger, spotted deer, wild boar, marine turtles, horse shoe crab etc.
- Uncontrolled fishing in the water of Reserve Forest area.
- Organizational and infrastructure deficiencies in tourism sector.
- Lack of public awareness/environmental education activities.

The Sundarbans, West Bengal

B) Thiruvakkarai Fossil Wood Park

Tamil Nadu's most amazing fossil trees preserved in rocks can be seen near Tiruvakkarai, in the district of Villupuram. These date to the Mio-Pliocene (20 m.y.). The trees are members of a number of endangered palm and conifer species. These trees were carried by rivers to their current locations of deposition in inland seas, as evidenced by the fact that they lack branches and roots. Conifer species that have been fossilised are typical in hilly areas that correspond to elevations of around 750 meters, which have since been peneplained to their current level.

Following petrification, the woody material was replaced by silica, and water was released as a result of the superposed sediments being compacted. The knots, pit structure, annular rings, and fine woody structure are all well preserved. Up to 200 fossil trees with girths of up to 5 meters and lengths ranging from 3 to 15 meters are found embedded horizontally in the Cuddalore Sandstone at Tiruvakkarai. The longest reported length is 28.80 meters. The fossil woods are categorised as angiosperms (*Peuce Schmidiana*) and gymnosperms (*Mesembrioxylon Schmidianum*). They include the following families: euphorbiaceae, guttiferae, leguminosae, anacardiceae and sonnaratiaceae. Several of them are members of the genera Shorea, Terminalia, Mangifera, Palmoxylon, and Albizzia. There are fossil woods that look like modern Tamarindus species.

Thiruvakkarai Fossil Wood Park, Tamil Nadu

Numerous researchers and organisations are interested in environmental protection, because it encompasses a variety of factors that need to be considered in Geotourism sites. As a result, proper attention and a multidisciplinary approach are necessary for the effective application of environmental protection. Action must be taken in a number of subsequent processes, such as the decision-making process, the evaluation of chosen approaches, area's ecological value, and its attractiveness in Geotourism sites. (Domaracká and colleagues, 2014; Trba and colleagues, 2015)

The idea of geo-tourism and geoparks is important to this endeavour because, in addition to the "classical" form of protection that focusses primarily on the preservation of the environment's abiotic components; it actively helps to alter the public's perception of the value of environmental preservation. Thus, this idea deserves sufficient attention since it is a sustainable and efficient way to safeguard the environment in addition to being an active type of tourism.

Reference

Raju M. and Niranjan K Singh. 2016. Geo-Tourism Hotspots of Indian Subcontinent, 36th International Geological Congress, 76-81.

Strba L., B. Krsak and M. Molokac. 2016. Geo-Tourism and Geoparks- A sustainable form of environmental protection, Production Management and Engineering Science, 279-283.

Garofano, M. and Gevoni, D. 2012. Underground Geo tourism a Historic and Economie Overview of Show Caves and Show Mines in Itals GobsT 4:79-92

Newsome, D. and Dowling, R.K. (Eds.). 2010. Geotourism: The Tourism of Geology and Landscape, Oxford: Goodfellow Publishers

Geological Survey of India, National Geological Monument. 2017. https://pib.gov.in/newsite/printrelease.aspx?relid=137573 (Accessed on 23 May 2017).

Press Information Bureau, Geo-Heritage Sites. 2016. https://pib.nic.in (Accessed on 15 September 2018).

Subramanian, K. S. and Selvan, T. A. 2001. Geology of Tamil Nadu and Pondicherry, Geological Society of India, Bangalore, Pp. 56.

Dowling, R.K. 2013. Global geotourism - An emerging form of sustainable tourism. Czech J. Tour.2013, 2: 59–79.

Henriques, M.H and Brilha, J. 2017. UNESCO Global Geoparks: A strategy towards global understanding and sustainability, 40, 349–355.

Willow variety registration in India: Genetic resource conservation, DUS advances and farmer clone recognition

Aditi Sharma[1] JP Shrama[2] and Shikha Thakur[2]

[1] Department of Silviculture and Agroforestry
[2] Department of Tree Improvement and Genetic Resources.
Dr. Yashwant Singh Parmar
University of Horticulture and Forestry, Solan, India

Abstract

Willow (***Salix*** spp.) holds ecological and economic importance in North-western Himalayas however, faces threats from climate change and genetic erosion. The study highlights the milestone of India's first farmer willow variety (DOODER-1) registration, reflecting growing farmer participation in formal conservation. It outlines the classification of willow varieties, the registration process and advances in DUS (Distinctness, Uniformity, Stability) testing under the PPV&FR Act (2001) in conserving Willow genetic resources, including the integration of Institutional research, coupled with farmer engagement, is shown to enhance genetic safeguarding, legal protection and benefit-sharing. These efforts support national agroforestry and biodiversity goals by ensuring the recognition and sustainable use of valuable willow clones. This work underscores the importance of sustainable agricultural practices and the role of variety registration in promoting environmental sustainability, with a particular focus on enhancing water conservation and forest ecosystem health through the cultivation of resilient *Salix* species.

Introduction

Willows (*Salix* spp.) are integral to temperate India, especially in the western Himalaya (Himachal Pradesh) and the Kashmir valley, where they supply fuelwood, basketry rods, cricket-bat timber, forage and riverbank protection services (Sharma et al., 2022). Rapid land-use change, interspecific hybridisation and erratic climate now threaten their genetic base (Dixit & Rawat, 2021). In this setting, plant-variety registration-anchored in the Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act, 2001) has emerged as both a legal and scientific tool for conserving diversity and rewarding innovation (PPV&FR Act, 2001). The PPV&FRA registry accepted India's first farmer-submitted willow clone in late 2024, marking a milestone in community-led conservation (certificate details published in the PPV&FRA Tree-Variety List, 2025 edition) (PPV&FRA, 2024)

Importance of Willow Variety Registration

Conservation of Genetic Resources

Official registration reduces genetic erosion by documenting descriptors, preserving reference material, and mandating maintenance breeding blocks, thereby safeguarding both traditional and improved clones for in-situ and ex-situ use (Vikaspedia, 2023).

Legal Protection and Ownership

A registered willow variety benefits from 18 years of protection (trees), during which breeders or farmers can license propagation material and collect benefit-sharing royalties (Kumar et al., 2019).

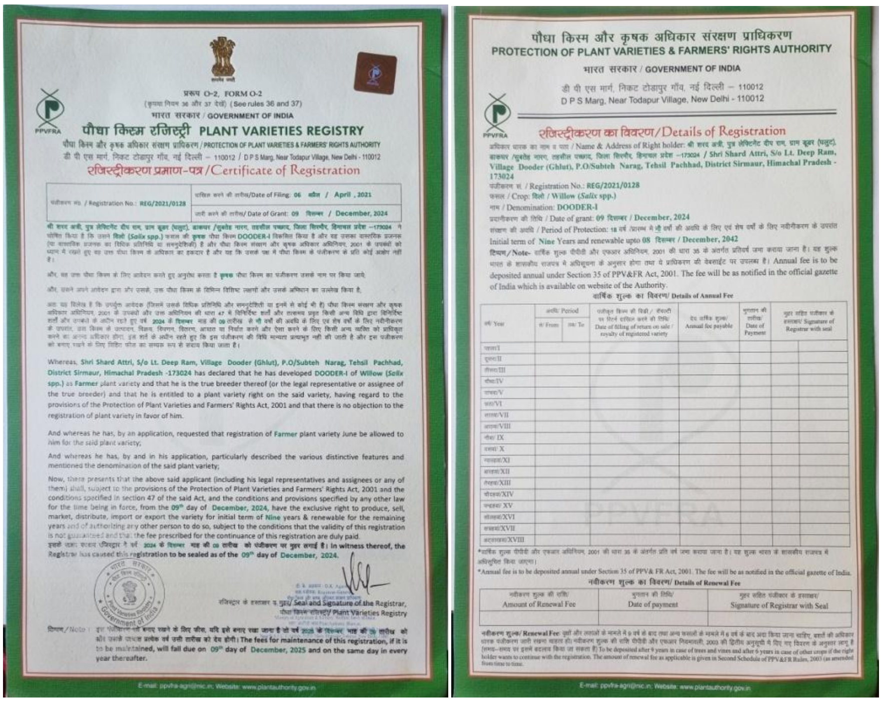
Clonal Identity and Standardisation

Unique denomination plus Distinctness–Uniformity–Stability (DUS) data enable forest departments, agro-industries, and farmers to source true-to-type cuttings, ensuring predictable growth, coppicing and wood quality across large plantings (PPV&FRA, 2024)

Farmer Variety registered so far under PPV&FR Act, 2001

Farmers in Himachal Pradesh have long maintained local clones selected for rapid sprouting and flexible rods. One such clone, distinguished by narrow lanceolate leaves and early autumnal leaf-fall, cleared two DUS cycles (2022–24) in Department of Tree Improvement & Genetic Resources Dr. Y.S. Parmar University of Horticulture & Forestry Nauni-173230, Solan and became India's first farmer-registered willow variety (PPV&FRA, 2024).

The Certificate of Registration for **DOODER-1**, dated 09-12-2024, has been officially issued and certified by the Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), Government of India**,** under the Ministry of Agriculture & Farmers Welfare, Department of Agriculture and Farmers Welfare, New Delhi**.**


FORM O-2
(See rules 36 and 37)
GOVERNMENT OF INDIA
पौधा किस्म रजिस्ट्री PLANT VARIETIES REGISTRY
PROTECTION OF PLANT VARIETIES & FARMERS' RIGHTS AUTHORITY
D P S Marg, Near Todapur Village, New Delhi - 110012
रजिस्ट्रीकरण प्रमाण-पत्र /Certificate of Registration

Registration No.: REG/2021/0128	Date of Filing: 06 / April, 2021
	Date of Grant: 09 / December, 2024

Whereas, Shri Shard Attri, S/o Lt. Deep Ram, Village Dooder (Ghlut), P.O/Subteh Narag, Tehsil Pachhad, District Sirmaur, Himachal Pradesh -173024 has declared that he has developed DOODER-I of Willow (Salix spp.) as Farmer plant variety and that he is the true breeder thereof (or the legal representative or assignee of the true breeder) and that he is entitled to a plant variety right on the said variety, having regard to the provisions of the Protection of Plant Varieties and Farmers' Rights Act, 2001 and that there is no objection to the registration of plant variety in favor of him.

And whereas he has, by an application, requested that registration of Farmer plant variety June be allowed to him for the said plant variety;

And whereas he has, by and in his application, particularly described the various distinctive features and mentioned the denomination of the said plant variety;

Now, these presents that the above said applicant (including his legal representatives and assignees or any of them) shall, subject to the provisions of the Protection of Plant Varieties and Farmers' Rights Act, 2001 and the conditions specified in section 47 of the said Act, and the conditions and provisions specified by any other law for the time being in force, from the 09th day of December, 2024, have the exclusive right to produce, sell, market, distribute, import or export the variety for initial term of Nine years & renewable for the remaining years and of authorizing any other person to do so, subject to the conditions that the validity of this registration is not guaranteed and that the fee prescribed for the continuance of this registration are duly paid.

In witness thereof, the Registrar has caused this registration to be sealed as of the 09th day of December, 2024.

Seal and Signature of the Registrar, Plant Varieties Registry

पौधा किस्म और कृषक अधिकार संरक्षण प्राधिकरण
PROTECTION OF PLANT VARIETIES & FARMERS' RIGHTS AUTHORITY
भारत सरकार / GOVERNMENT OF INDIA
D P S Marg, Near Todapur Village, New Delhi - 110012
रजिस्ट्रीकरण का विवरण/Details of Registration

Name & Address of Right holder: Shri Shard Attri, S/o Lt. Deep Ram, Village Dooder (Ghlut), P.O/Subteh Narag, Tehsil Pachhad, District Sirmaur, Himachal Pradesh - 173024
Registration No.: REG/2021/0128
Crop: Willow (Salix spp.)
Denomination: DOODER-I
Date of grant: 09 December, 2024
Period of Protection: Initial term of Nine Years and renewable upto 08 December, 2042
Note- Annual fee is to be deposited annual under Section 35 of PPV&FR Act, 2001. The fee will be as notified in the official gazette of India which is available on website of the Authority.

Details of Annual Fee

Certificate of Registration (2024)

The Registration Process

Eligibility Criteria

Four categories qualify: new, extant, farmer and essentially-derived varieties (EDV). All must meet DUS principles-distinctness, uniformity and stability [3] (PPV&FR Act, 2001).

Application Submission

Applicants file Form I (new) or Form II (extant/farmer) with passport data, origin story, photographs, and a 3-year seed/propagule sample PPV&FR Act, 2001).

DUS Testing Procedure

PPV&FRA mandates two growth cycles at designated centres: Department of Tree Improvement and Genetic Resources, College of Forestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan (Himachal Pradesh)

The leaf data was recorded in the month of August, growth data in the month of December and sprouting in the month of January – February.

The DUS characters for each variety of willow (*Salix spp.*) under maintenance testing were validated which have already been published by Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA, 2024).

Method of testing

- Testing Duration: Conducted over two growing seasons with consecutive plantings using material from the first crop.
- Testing Locations: Trials held at one primary site
- Additional testing at a third location if key traits were not expressed.
- Growth Conditions: Maintained optimal environmental conditions to ensure proper trait expression.
- Data Collection: growth, leaf morphology and sprouting.
- Non-destructive measurements allowed full-cycle observations.
- Compliance: Ensured adherence to DUS criteria for variety registration.

Test Plot Design

- Number of Cuttings: 20 per variety
- Row-to-Row Distance: 50 cm
- Plant-to-Plant Distance: 40 cm
- Number of Replications: 3
- Main Shoot & Branches: October–November
- Leaf Traits: July–August (mature leaves from the middle third of the main shoot)
- leaf Fall: November–December; clone standardization in early December
- Leaf Emergence: January–February; clone standardization in early February

Gazette Notification and Objections

After positive DUS data, the proposed denomination is published in the *Plant Variety Journal of India*; any opponent has 90 days to lodge objections

Issuance of Certificate

If uncontested, the Authority grants a certificate valid for 18 years, renewable annually on fee payment; farmers are exempt from fees

Advances in DUS Testing of Willow

Trait Characterisation

Indian DUS work on 49 hybrids showed wide dispersion for lamina length, petiole pubescence, bark lenticels pattern, and coppice shoot colour, providing robust distinctness thresholds (Sharma et al., 2022). Seasonal characters—first sprout, full leaf-fall, and frost hardening-are now coded as additional descriptors in the draft willow guideline (PPV&FRA, 2024).

Field trials of DUS Centre for Willow

Qualitative and quantitative characters (leaf and stem) of *Salix* varieties

Challenges and Opportunities

Environment-induced plasticity can blur clone boundaries; thus repeat scoring across two sites is advised. Willow, being dioecious and highly out-crossing, also shows intra-clone somatic mutation, complicating uniformity scoring (Singh et al., 2015)

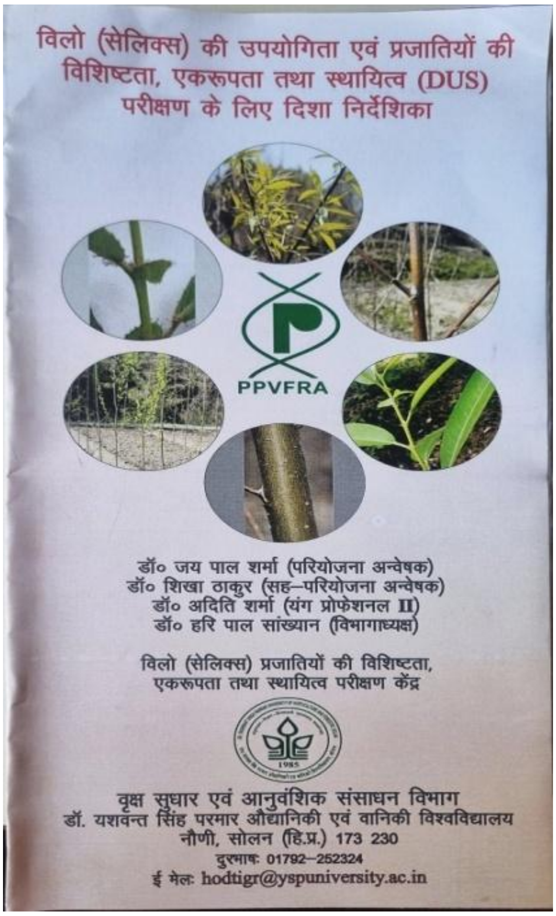
Role of Research Institutions and Farmers

Institutional Contributions

The Department of Tree Improvement & Genetic Resources (Dr Y.S. Parmar University) maintains 51 hybrids and 21 farmer clones, documenting traits mentioned in DUS guidelines (trial cycles 2022–26). Their DUS database for DUS trials feeds directly into PPV&FRA dossiers.

Farmer Participation and Recognition

Training cum Awareness Camps were conducted in district Kangra (Alampur, Palampur Jawalaji) and district Hamirpur (Bhota, badsar, Sujanpur) and district Una (Lathiyani and Bangana) in December 2024, and in district Chamba (Chamba,Bhanota ,Kandla, Khajjiar and Kiani) in March 2025. These camps aimed to educate farmers and Panchayat officials about registering farmer-bred willow varieties with PPV&FRA. Farmer interactions and pamphlet distribution encouraged farmers to document and submit unique willow germplasm for formal recognition. The initiative focused on promoting awareness, conservation, and registration of valuable willow varieties. The first farmer registrant now receives licence fees and public recognition during PPV&FRA's 20th Foundation Day celebrations (Times of India, 2024)



Extension article (pamphlet)

Policy and Conservation Implications

Variety registration strengthens India's bio-economy vision by ensuring traceable, high-quality planting stock for agroforestry, river-training projects, and bio-energy plantations. It dovetails with the National Agroforestry Policy (2014, 2023) those targets five million ha of tree-outside-forest plantings (Ministry of Agriculture, 2023). Registered high-biomass clones also qualify for carbon-credit accounting under UNFCCC-aligned schemes, amplifying climate-mitigation benefits (UNFCCC, 2021) simultaneously, the Act's farmers' rights clauses (Section 39) guarantee equitable benefit sharing and community-based conservation Vikaspedia. (2023).

Conclusion

Willow variety registration has progressed from a bureaucratic novelty to a cornerstone of genetic-resource conservation and rural innovation. Robust DUS protocols, augmented with molecular fingerprints, are making distinctness testing faster and more reliable. Institutional research, coupled with proactive farmer participation, delivered India's first farmer-recognised willow clone-proof that legal protection and grassroots stewardship can coexist. Future priorities include: (i) finalizing willow-specific DUS descriptors, (ii) mainstreaming SSR/DArTseq diagnostics for EDV confirmation, and (iii) strengthening benefit-sharing mechanisms so that every superior farmer clone enters national germplasm repositories while rewarding its custodians.

References

Sharma, J.P., Thakur, S., Sharma, A., Sankhyan, H.P. (2022). Genetic diversity in *Salix tetrasperma* using molecular markers. *Journal of Tree Genetic Resources*, 12(1), 45–53.

Dixit, A. & Rawat, G.S. (2021). Impact of land-use change on Himalayan willow ecosystems. *Ecological Perspectives*, 29(3), 201–210.

PPV&FR Act, 2001. Protection of Plant Varieties and Farmers' Rights Authority, Govt. of India.

PPV&FRA. (2024). *Tree Variety DUS Guidelines and Gazette Notifications*. Retrieved from https://plantauthority.gov.in/

Rao, S. & Sinha, R. (2020). Genetic erosion and the role of variety registration in India. *Indian Journal of Plant Genetic Resources*, 33(2), 90–97.

Vikaspedia. (2023). Benefit sharing under PPV&FRA. Retrieved from https://vikaspedia.in/agriculture/ppvfra

Kumar, M. et al. (2019). Clonal forestry and identity preservation: Role of DUS testing. *Agroforestry Systems*, 93(4), 1125–1137.

PPV&FRA. (2024). Application forms and procedural guidelines for tree registration. Retrieved from https://plantauthority.gov.in/

Kapoor, D. & Rana, R. (2022). Challenges in DUS testing for clonally propagated trees. *Indian Journal of Forestry*, 45(2), 155–161.

Sharma, J.P. et al. (2022). RAPD and ISSR-based variation in *Salix tetrasperma*. *Journal of Tree Genetic Resources*, 12(1), 45–53.

Singh, N.B., Kumari, S., & Koundal, R. (2015). Genetic diversity of willow genotypes using SSR and RAPD. *Indian Journal of Plant Genetic Resources*, 28(2), 179–185.

Times of India. (2024). Farmer honoured for first willow variety registration. Retrieved from https://timesofindia.indiatimes.com/

Ministry of Agriculture. (2023). *National Agroforestry Policy Update*. Government of India.

UNFCCC. (2021). *Carbon Stock Guidelines in Agroforestry*. Bonn: UN Climate Secretariat.

Annatto seeds as a natural dye source for cotton fabric

K.V. Murali[1*], Gajendra C.V.[2] and Nayana M.D.[3]

[1]Dept. of Forest Resource Management, College of Forestry, Vellanikkara, KAU, Thrissur, Kerala, 680656, India
[2]Dept. of Forest Biology and Tree Improvement, College of Forestry, Ponnampet, KSNUAHS, Shivamogga, Karnataka (577412), India
[3]Dept. of Forest Products and Utilization, College of Forestry, Sirsi, Karnataka (581401), India
*E-mail: muralikv536@gmail.com

Abstract
The study investigates the environmentally safe way of extracting natural dye from *Bixa Orellana* (Annatto) seeds that were gathered in the vicinity of the College of Forestry, Ponnampet, Kodagu. The seeds yielded 29.7% dye after being shade-dried and dye-extracted at 60°C for 45 minutes using a 5:100 material-to-liquor ratio. Before being dyed, cotton textiles were pre-mordanted with 20% mordants. While rubbing fastness varied from acceptable to good, wash fastness was often low. Chromophores' photo-oxidation affected light fastness. Under acidic and alkaline sweat conditions, samples mordanted with copper sulphate exhibited the highest fastness, demonstrating the promise of Bixa dye as a sustainable substitute in the textile industry.

Keywords: *Bixa orellana*, Colour fastness tests, Cotton fabric, Dye

Introduction

Natural dyes are colouring substances derived from renewable resources like plants, animals, and minerals, offering a sustainable alternative to synthetic dyes (Manley *et al*., 2023). Plants remain the dominant source of natural dyes, with over 500 dye-yielding species reported globally. However, only a small fraction around 150 has been commercially exploited (Ahsan*et al.*, 2020). Plant-based dyes can be extracted from various parts such as roots, leaves, barks, fruits, and seeds (Bechtold and Mussak, 2016). With increasing consumer demand for eco-friendly and non-toxic textile products, natural dyes have regained attention in the 21st century due to their biodegradability and minimal environmental impact (Li *et al.*, 2022).

Synthetic dyes, although widely used, contribute significantly to environmental degradation through chemical effluents that contaminate water and soil, posing risks to aquatic life and human health (Yusuf *et al.*, 2017). In contrast, natural dyes such as Annatto (from *Bixa orellana*) offer low toxicity and exhibit antimicrobial, antioxidant, and UV-protective properties, making them particularly suitable for textiles that come into direct contact with skin (Rather *et al.*, 2016).

Annatto, a carotenoid-based dye, contains two key pigments bixin and norbixin responsible for its characteristic orange-red hue. Bixin constitutes approximately 80% of annatto's total carotenoids (Hirko *et al.*, 2022). Its wide applications span food colouring, cosmetics, pharmaceuticals, and textile industries. Despite being one of the few natural dyes approved by the USFDA, its use in textile dyeing remains underexplored compared to its use in food and cosmetics (Yadav *et al.*, 2023).

Recent studies have shown that *Bixa orellana* extracts can serve as eco-friendly dyeing agents for textiles and leather, with acceptable fastness properties when used with appropriate mordants (Shridar *et al.*, 2024; Selvi *et al.*, 2013). However, literature reveals limited work on optimizing extraction parameters, standardizing dyeing protocols for cotton fabrics, and evaluating fastness properties under varying conditions- leaving a notable research gap.

This study aims to investigate the dye extraction from annatto seeds, apply the dye on cotton fabric, and assess colour fastness under various conditions. This research explores the potential of annatto as a sustainable alternative dye for textile processing, with the key objectives of extracting natural dye from *Bixa orellana* seeds, dyeing cotton fabrics, and evaluating the dyed fabrics through various colour fastness tests.

Materials and Methods

Experimental Material

The study utilized seeds from the *Bixa orellana* plant as the experimental dye source (commonly known as Annatto). Mature pods were collected using secateurs from standing trees situated in Ponnampet, South Coorg, Karnataka, India (12°08'33.62"N, 75°56'20.19"E). Seeds were carefully extracted from these pods using sterilized sharp knives. The seeds were shade-dried for 2-3 days by evenly spreading them on clean muslin cloth in a well-ventilated room under ambient conditions viz., Temperature (28–32 °C), Relative humidity (55–65%) to avoid direct sunlight exposure, and pigment degradation (Bindyalaxmi *et al*., 2022).

Aqueous Dye Extraction

Exactly 100 g of shade-dried annatto seeds were taken and crushed to break the seed coat. They were extracted in 1 L of aqueous ethanol (10% ethanol in distilled water) at 60 °C for 45 minutes using a magnetic stirrer-heater. After extraction, the solution was allowed to cool and then filtered using Whatman No. 1 filter paper. The resulting dye extract was stored in an amber conical flask at 4 °C until further use to prevent pigment degradation (Gajendra *et al.*, 2019).

Figure 1: Extraction of Annatto dye a. Seeds extraction b. Cleaning and drying c. Annatto dye

Selection and Pre-treatment of Fabric

For dyeing, 100% cotton fabric (plain weave, 60 g/m²) was procured from a certified textile supplier. Fabric samples were cut into 30 cm × 10 cm pieces. Before dying, fabrics underwent scouring using 1 g/L of non-ionic soaping agent (pH ~7) at 60 °C for 30 minutes, followed by hot and cold-water rinses to remove natural and industrial impurities. The cleaned fabrics were then shade-dried under ambient conditions.

Mordanting Process

Fabric samples were immersed in a solution containing 20% weight of mordant relative to fabric weight, at 60 °C for 30 minutes, using a material-to-liquor ratio (MLR) of 1:40. After mordanting, samples were rinsed and air-dried in shade before dying (Tayade and Adivarekar, 2013).

Volume of water (mL) = Weight of fabric (g) x 40

Amount of mordant (g) = (20/100) x Weight of fabric (g)

Selection of Mordants

Mordants were selected based on their eco-friendliness, bonding efficiency, and ability to enhance fastness and shade variation. The different mordants used for the study are shown in Table 1.

Table 1: Different mordants used for the study

Treatment	Mordant Used	Type and Role
T1	Control (No Mordant)	Baseline
T2	Beetle Leaf Extract	Natural mordant; mild astringency & tannins
T3	Copper Sulphate ($CuSO_4$)	Metallic; improves brightness and fastness
T4	Myrobalan (*Terminalia chebula*)	Natural tannin-based mordant
T5	Stannous Chloride ($SnCl_2$)	Metallic; enhances specific shades
T6	Vinegar (Acetic Acid ~5%)	Natural acid; adjusts pH, assists pigment fixation
T7	$CuSO_4$ + Myrobalan	Synergistic metallic-tannin complex
T8	$CuSO_4$ + Beetle Leaf Extract	Synergistic combination
T9	$CuSO_4$ + Vinegar	Metallic + pH adjuster

Dyeing Procedure

Mordanted fabrics were dyed using the freshly prepared annatto dye extract at an MLR of 1:40. Dyeing was conducted at 60 °C for 45 minutes under continuous stirring. After dyeing, fabrics were rinsed in cold water to remove unfixed dye, air-dried in shade, and conditioned for 24 hours before testing.

Colour Fastness Evaluation

Colour Fastness to Washing

The wash fastness of annatto-dyed cotton fabric was assessed according to ISO 105 C03 (1989). A fabric sample measuring 30 cm × 10 cm was used. The specimen was immersed in a washing solution containing 5 g/L of soap and 2 g/L of anhydrous sodium carbonate at 60 ± 2 °C for 30 minutes using a liquor ratio of 1:50. After the wash cycle, the specimens were rinsed in cold and tap water, and then dried. The degree of colour change and staining on the adjacent fabrics was evaluated using the grey scale rating system.

Colour Fastness to Rubbing

Rubbing fastness was evaluated following ISO 105 X12 (2001) to determine the extent of colour transfer through friction. For dry rubbing, the dyed fabric was mounted on a crock meter and rubbed using a standard white rubbing cloth for 10 complete back-and-forth cycles (100 mm track). In the case of wet rubbing, the test cloth was first moistened with distilled water and squeezed before rubbing. The degree of staining on the rubbing cloth in both tests was then compared to the grey scale for staining and rated accordingly.

Colour Fastness to Light

Light fastness was determined under ISO 105 B02 (2013), which recommends the use of a xenon arc lamp to simulate natural daylight. Fabric specimens were mounted on paper cards and placed in the specimen holder of the testing apparatus. The samples were exposed to light until a visible change equivalent to grade 4 on the grey scale was observed, followed by exposure until a grade 3 change was reached. This test assessed the extent of photo-degradation or fading due to light exposure.

Colour Fastness to Perspiration

Perspiration fastness was tested according to ISO 105 E04 (2014), using both acid and alkaline-simulated perspiration solutions. Fabric samples were placed in contact with fabric, immersed in the respective solutions, and then pressed under controlled pressure in a perspirometer at 37 °C for 4 hours. After incubation, the samples were dried and evaluated for colour change and staining using grey scales. This test simulated the effects of human sweat on dye stability in fabric.

Results and Discussion

Evaluation of Dyed Cotton Fabric for Various Colour Fastness Tests

The environmental concerns associated with synthetic dyes, including water pollution, toxicity, and non-biodegradability, have led to increased interest in natural dye alternatives. Annatto (*Bixa orellana*), a carotenoid-rich natural dye, has gained attention for its eco-friendly profile, biodegradability, and potential in sustainable textile applications. Recent literature (Bechtold *et al.*, 2003; Samanta, 2020) highlights the adverse effects of synthetic dyes on aquatic life and human health, reinforcing the need for greener alternatives. Annatto’s ability to impart a range of yellow to orange shades, coupled with its compatibility with plant-based mordants, makes it a viable natural option. This study aims to evaluate the dyeing potential and color fastness of annatto-dyed cotton using various mordants, thereby contributing to the development of sustainable textile practices.

Colour Fastness to Washing

The resistance of a material to change in any of its color characteristics when subjected to washing is termed color fastness to washing (ISO, 1989). Wash fastness was assessed using grey scale values for colour change and staining on adjacent multifibre fabrics. Cotton, silk, and wool samples pre-mordanted with 20% of various mordants and dyed with annatto exhibited noticeable to considerable changes in colour. Myrobalan (T4)-treated cotton showed minimal staining on adjacent fibers (rating: 4-5), while wool and cotton revealed slight changes (4) and noticeable to considerable change (2-3), respectively (Table 1).

In agreement, Zhu *et al.*, (2024) observed that β-carotene dyestuffs (carrot, orange peel) also displayed minimal dye retention on cotton post-washing at 60 °C for 30 min. Rajiv *et al.* (2013) found conventional dyeing resulted in poor wash fastness (rating: 2–3), attributed to low dye fixation on enzyme-treated fibers. Similarly, Ding *et al*. (2017) highlighted the incompatibility between dye and mordant under traditional dyeing methods, suggesting a need for alternative mordanting or post-treatment approaches to improve fixation.

Colour Fastness to Rubbing

Colour fastness to rubbing (Table 2) was assessed under dry and wet conditions. All mordanted and unmordanted cotton fabrics exhibited good to excellent fastness under dry rubbing (rating: 4-5). However, under wet conditions, mordanted fabrics showed decreased fastness (rating: 2-3), while unmordanted samples performed slightly better (rating: 3-4) (Table 1).

These results are consistent with Mohini *et al*. (2018) in *Thespesia populnea* and Gulzar *et al.* (2015) in *Acacia nilotica* pods, where natural dyes showed good performance under both dry and wet rubbing. The performance drop under wet conditions highlights the need to improve dye penetration or binding through optimized mordanting.

Table 1: Evaluation of Annato dyed cotton fabrics for colour fastness to washing and rubbing

Treatments	Colour fastness to washing	Colour fastness to rubbing	
		Dry rub	Wet rub
T_1	3-4	3-4	2-3
T_2	4	5	2-3
T_3	3-4	4-5	2-3
T_4	4	4-5	2-3
T_5	3-4	4	2-3
T_6	4	5	2-3
T_7	3-4	3-4	2-3
T_8	4	4-5	2-3
T_9	3-4	5	2-3

Colour Fastness to Light

Light fastness results (Table 2) revealed low resistance to fading for both mordanted and unmordanted cotton fabrics, with greyscale ratings around 2. A slight improvement was noted in samples treated with Myrobalan + Copper Sulphate (rating: 2–3).

This aligns with the known limitations of natural dyes, which typically degrade under UV exposure due to photodegradation mechanisms (Burkinshaw, 2001). Padfield and Landi (1996) also reported poor light fastness in cotton compared to wool, attributing this to oxidative pathways affecting indigo dyes. Enhancing dye concentration or exploring advanced mordanting combinations may mitigate this issue (Saravanan *et al*., 2014).

Colour Fastness to Perspiration

Perspiration fastness was evaluated under acidic and alkaline conditions (Table 2).

Myrobalan (T4)-treated cotton achieved a grey scale rating of 4 in both conditions, indicating good resistance. Treatments with Vinegar (T6), Copper Sulphate (T3), Betel Leaves + Copper Sulphate (T8), Vinegar + Copper Sulphate (T9), and Myrobalan + Copper Sulphate (T7) yielded moderate resistance (rating: 3 acidic; 3–4 alkaline). Betel Leaves (T2) recorded the lowest performance (rating: 2–3 acidic; 3 alkaline).

These values align with previous research Ahmad *et al.* (2011) in Gluta aptera, Anshu and Ekta (2011) in walnut bark dye, and Kumaresan (2014) in Achras sapota and *Cordia sebestena*, which demonstrated well to excellent fastness under perspiration.

Table 2: Evaluation of Annato dyed cotton fabrics for colour fastness to washing and rubbing

Treatments	Colour fastness to light	Colour fastness to perspiration
T_1	2-3	3-4
T_2	2-3	4
T_3	2-3	3-4
T_4	**5**	4
T_5	2-3	3-4
T_6	2-3	4
T_7	**5**	3-4
T_8	2-3	4
T_9	2-3	3-4

Colour Change (CC*) = 5 - No change (Excellent), 4 - Slightly changed (Good), 3 - Noticeably changed (Fair), 2 - Considerably changed (Poor), 1 - Much changed (Very poor)

The extraction conditions temperature, time, and material-to-liquor ratio directly influence dye yield and fixation. Optimized parameters enhanced dye uptake and uniformity of colouration. Comparison with earlier studies reveals that annatto, though vibrant, suffers from limited wash and light fastness. Alternative mordanting strategies or after-treatment (e.g., bio-mordants, polymer fixatives) may enhance durability. This study demonstrates that combining natural and metallic mordants can slightly improve performance, but further refinement is required.

Colour Fastness Analysis

The differences in fastness between treatments are attributed to the varied chemical affinities of mordants to both dye and fibre. Tannins in myrobalan, acetic acid in vinegar, and copper ions all interact differently with the hydroxyl and amino groups in cotton, influencing dye stability. Mordants such as copper sulphate form coordination complexes, enhancing dye adherence, whereas plant-based mordants like betel leaves may offer less consistent fixation. Exploring the molecular interactions at the fibre dye mordant interface can inform improved formulations. Recent studies (Khatun *et al*., 2017; Chengaiah *et al*., 2010) support the importance of such understanding for optimizing natural dyeing processes

Conclusion

In this study, optimal dye extraction from *Bixa orellana* seeds was achieved at 60 °C for 40 minutes with a material-to-liquor ratio of 5:100, yielding 29.7% dye. Colour fastness refers to a fabric's resistance to colour changes or dye transfer under various conditions such as washing, dry cleaning, heat, light, and perspiration. Natural acid dyes like carotenoids typically exhibit poor affinity for cotton fibres; however, their fastness properties can be enhanced through the use of mordants.

In wash fastness tests, cotton samples pre-mordanted with 20% myrobolan exhibited slight (4) to considerable (2-3) colour change on cotton. This indicates low compatibility between the dye and the mordant, suggesting the need for improved dyeing methods or alternative mordants. Regardless of the mordant used, colour fastness to rubbing tests on cotton samples demonstrated fair to good results. The chemical structure of dyes, comprising chromophores and auxochromes, influences light fastness. Natural dyes generally have poor light fastness due to photo-oxidation of the chromophore. This degradation can be mitigated by forming dye-metal complexes through post-mordanting, which was not employed in this study. Therefore, implementing post-mordanting could enhance light fastness by facilitating dye-metal-fibre bond formation. Colour fading and alteration can result from reactions between dyes and components of human perspiration. In this study, cotton samples mordanted with copper sulphate exhibited better fastness ratings under both acidic and alkaline perspiration conditions compared to other mordants.

References

Ahmad, W.Y.W., Rahim, R., Ahmad, M.R., Kadir, M.I.A. and Misnon, M.I., 2011. The application of Gluta aptera wood (Rengas) as natural dye on silk and cotton fabrics. *Univers. J. Environ. Res. Technol*, *1*(4), pp.545-551.

Ahsan, R., Masood, A., Sherwani, R. and Khushbakhat, H., 2020. Extraction and application of natural dyes on natural fibers: an eco-friendly perspective. *Review of Education, Administration & LAW*, *3*(1), pp.63-75.

Anshu Sharma, A.S. and Grover, E., 2011. Colour fastness of walnut dye on cotton.

Bechtold, T. and Mussak, R. eds., 2009. *Handbook of natural colorants* (Vol. 8). John Wiley & Sons.

Bechtold, T., Turcanu, A., Ganglberger, E. and Geissler, S., 2003. Natural dyes in modern textile dyehouses-how to combine experiences of two centuries to meet the demands of the future?. *Journal of Cleaner Production*, *11*(5), pp.499-509.

Bindyalaxmi, K., Kumaran, K., Divya, M.P., Vennila, S., Raveendran, M., Radha, P. and Priyanka, V., 2022. Pigment and oil content estimation in seeds of Bixa orellana L. *L. The Pharma Innovation*, *11*(1), pp.419-423.

Burkinshaw, S.M., Son, Y.A. and Bide, M.J., 2001. The aftertreatment of acid dyes on nylon 6, 6 fibres: part 2. Non-metallised acid dyes. *Dyes and pigments*, *48*(3), pp.209-215.

Chengaiah, B., Rao, K.M., Kumar, K.M., Alagusundaram, M. and Chetty, C.M., 2010. Medicinal importance of natural dyes-a review. International Journal of PharmTech Research, 2(1), pp.144-154.

Ding, Y.I. and Freeman, H.S., 2017. Mordant dye application on cotton: optimisation and combination with natural dyes. *Coloration Technology*, *133*(5), pp.369-375.

Gajendra, C.V. and Kumaran, K., 2019. Eucalyptus bark as a source of natural dye for cotton fabric. *International Journal of Current Microbiology and Applied Sciences*, *8*(5), pp.872-882.

Gulzar, T., Adeel, S., Hanif, I., Rehman, F., Hanif, R., Zuber, M. and Akhtar, N., 2015. Eco-friendly dyeing of gamma ray induced cotton using natural quercetin extracted from acacia bark (*A. nilotica*). *Journal of Natural Fibers*, *12*(5), pp.494-504.

Hirko, B. and Getu, A., 2022. Bixa orellana (Annatto Bixa) A review on use, structure, extraction methods and analysis. *Journal of Agronomy, Technology and Engineering Management*, *5*(1), pp.687-696.

Khatun, M.H., Akhter, A., Kadri, H.J. and Mostafa, M., 2017. Optimization of alkaline extraction of natural dye from Acacia catechu and its dyeing on silk fabrics. *J. Environ. Sci.*, *6*, pp.111-117.

Kumaresan, M., 2014. Comparison of Fastness Properties of Dyed Cotton Fabric with Eco-Friendly Natural Dyes Obtained fromAchras sapota and Cordia Sebestena. *J. Environ. Nanotechnol*, *3*(1), pp.60-66.

Li, K., Ding, Q. and Zhang, H., 2022. Eco-friendly dyeing of cotton fabric using natural dye from orange peel. *The Journal of the Textile Institute*, *113*(3), pp.360-366.

Manley, A., Seock, Y.K. and Shin, J., 2023. Exploring the perceptions and motivations of Gen Z and Millennials toward sustainable clothing. Family and Consumer Sciences Research Journal, 51(4), pp.313-327.

Mohini, K., Tejashree, L. and Vijay, N., 2018. Dataset on analysis of dyeing property of natural dye from Thespesia populnea bark on different fabrics. *Data in brief*, *16*, pp.401-410.

Padfield, T. and Landi, S., 1966. The light-fastness of the natural dyes. *Studies in conservation*, *11*(4), pp.181-196.

Rajiv, P., Rajeshwari, S. and Venckatesh, R., 2013. Bio-Fabrication of zinc oxide nanoparticles using leaf extract of Parthenium hysterophorus L. and its size-dependent antifungal activity against plant fungal pathogens. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *112*, pp.384-387.

Rather, L.J. and Mohammad, F., 2016. Phytochemistry, biological activities and potential of annatto in natural colorant production for industrial applications–A review. *Journal of advanced research*, *7*(3), pp.499-514.

Samanta, A.K., 2020. Bio-dyes, bio-mordants and bio-finishes: scientific analysis for their application on textiles. *Chemistry and technology of natural and synthetic dyes and pigments*, pp.3-42.

Saravanan, P., Chandramohan, G., Mariajancyrani, J. and Kiruthikajothi, K., 2014. Eco-friendly dyeing of cotton fabric with a natural dye extracted from flowers of Lantana Camara Linn. International Journal of Bioassays, 3(1), pp.1653-1656.

Selvi, A.T., Aravindhan, R., Madhan, B. and Rao, J.R., 2013. Studies on the application of natural dye extract from Bixa orellana seeds for dyeing and finishing of leather. *Industrial crops and products*, *43*, pp.84-86.

Shridar, B., Paramadhas, S., Palanisamy, P., Kalyanasundaram, K., Marimuthu, S. and Pandiselvam, R., 2024. Microencapsulation of mechanically extracted annatto for improved use in food products. *Microchemical Journal*, *205*, p.111282.

Tayade, P.B. and Adivarekar, R.V., 2013. Dyeing of silk fabric with Cuminum Cyminum L as a source of natural dye. *International Journal of ChemTech Research*, *5*(2), pp.699-706.

Yadav, S., Tiwari, K.S., Gupta, C., Tiwari, M.K., Khan, A. and Sonkar, S.P., 2023. A brief review on natural dyes, pigments: Recent advances and future perspectives. *Results in Chemistry*, *5*, p.100733.

Yusuf, M., Shabbir, M. and Mohammad, F., 2017. Natural colorants: Historical, processing and sustainable prospects. *Natural products and bioprospecting*, *7*, pp.123-145.

Zhu, D., Zhang, J. and Xiao, P., 2024. Naturally Occuring or Derived Photoinitiators for Medical Applications. *Advanced Optical Materials*, *12*(22), p.2400738.

Tamarind (*Tamarindus Indica* L.): A multipurpose tree species for agroforestry, nutrition, and sustainable land use

Ajay Patel[1*], Yashmita Ulman[2], Devendra Kumar[3]

Department of Silviculture and Agroforestry
College of Horticulture and Forestry, ANDUAT University, Ayodhya (UP)-224229, India
E-mail id: ajaypatel969628@gmail.com

Abstract

Tamarindus indica L., commonly known as the tamarind tree, is a long-lived, multipurpose leguminous species native to tropical Africa and widely cultivated across South Asia. Renowned for its tangy fruit pulp, the species contributes significantly to rural economies through food, fodder, timber, fuelwood, and medicinal uses. Its adaptability to semi-arid and degraded lands, nitrogen-fixing ability, and deep-rooted structure make it suitable for agroforestry and reforestation initiatives. This article comprehensively reviews the botany, ecological adaptability, propagation techniques, uses, and socioeconomic importance of tamarind, highlighting its potential in climate-resilient agriculture and land restoration programs.

Keywords: Tamarindus indica, agroforestry, arid zone tree, non-timber forest product (NTFP), ethnobotany, sustainable agriculture, dryland horticulture

Introduction

The tamarind tree (Tamarindus indica L.) belongs to the family Fabaceae and is one of the most versatile and economically important tropical fruit trees. While its origin is traced to Africa, it has become naturalized and widely cultivated in South Asia, particularly in India, which is currently the largest producer and exporter. The species thrives in diverse agroclimatic zones, ranging from semi-arid to sub-humid regions, and is commonly incorporated in homesteads, boundary plantations, and agroforestry systems.

Botanical Description

Fig. 1 Tamarind Tree

Tamarindus indica is a slow-growing, deciduous to semi-evergreen tree that can attain a height of 20–25 meters with a broad, dome-shaped crown. It exhibits pinnately compound leaves, yellowish flowers with reddish streaks, and indehiscent pods containing a sticky, acidic pulp. The seed is hard-coated, brown, and viable for several months if stored under appropriate conditions.

Taxonomy:

- **Kingdom:** Plantae

- **Order:** Fabales
- **Family:** Fabaceae
- **Genus:** ***Tamarindus***
- **Species:** ***T. indica***

Ecological Adaptability

Tamarind is known for its hardiness and drought tolerance. It thrives well in Annual rainfall of 500–1500 mm, Soil pH range of 5.5–8.5, Temperatures ranging from 25–35°C. It grows well on marginal lands, gravelly soils, and light-textured lateritic areas. Its deep-rooting system prevents soil erosion and enhances soil structure, making it an ideal candidate for soil and water conservation efforts.

Propagation and Cultivation Practices

Propagation

Traditionally propagated by seeds; however, grafting, air-layering, and budding are increasingly used for faster fruiting and true-to-type plant production.

Planting

- Spacing: 10–12 m × 10–12 m in orchard systems
- Pit size: 1 m^3 filled with FYM and topsoil
- Irrigation: Required during establishment and dry spells
- Pruning: Minimal pruning required to shape young trees

Pests and Diseases

Generally resistant but may be affected by mealybugs, borers, and fungal leaf spots.

Uses and economic importance

Fruit and food products

The pulp is used in culinary preparations, beverages, chutneys, candies, and preservatives. Rich in tartaric acid, vitamin C, calcium, and dietary fiber.

Timber and Fuelwood

The heartwood is durable, termite-resistant, and used for furniture, tool handles, and agricultural implements. Wood serves as excellent fuelwood with high calorific value.

Medicinal Value

Bark and leaves possess antimicrobial, anti-inflammatory, and astringent properties. Used in traditional medicine to treat fever, constipation, and digestive disorders.

Fodder and Green Manure

Leaves serve as fodder for goats and cattle during dry seasons. Litter contributes organic matter and enhances soil fertility.

Role in agroforestry and sustainable land use

Tamarind fits well in various agroforestry models such as: Agri-horticultural systems (with legumes, cereals), Silvi-pastoral systems (fodder grass under canopy), Boundary and live-fence plantations. Its nitrogen-fixing potential (through rhizosphere interactions), minimal input requirement, and perennial nature enhance long-term productivity, biodiversity conservation, and carbon sequestration, aligning with climate-resilient strategies.

Socioeconomic and Cultural Significance

In India and Southeast Asia, tamarind is intertwined with local cuisines, traditional rituals, and rural livelihoods. Women often engage in its collection, pulp processing, and value-added products, contributing to gender-inclusive development. The tree's low maintenance and multi-utility characteristics have made it a reliable asset for smallholder farmers and tribal communities.

Challenges and Future Prospects

Despite its utility, tamarind remains underutilized in commercial horticulture due to:

- Long gestation period
- Lack of improved cultivars
- Inadequate post-harvest infrastructure
- Unorganized marketing

Future interventions may include:

- Genetic improvement through clonal selection and biotechnology
- Value chain development and market integration
- Promotion under agroforestry schemes and MNREGA-linked afforestation programs

Conclusion

Tamarindus indica L. stands out as a promising multipurpose tree species with immense ecological, nutritional, and economic value. With targeted research, policy support, and farmer-level interventions, tamarind can significantly contribute to sustainable livelihoods, land rehabilitation, and climate change mitigation in tropical and subtropical regions.

References

Ahmad, R., & Qureshi, M. I. (2019). Tamarindus indica: An overview of its nutritional, medicinal, and agroforestry potential. *Journal of Tropical Agriculture*, 57(3), 45–53.

Gunasena, H. P. M., & Hughes, A. (2000). Tamarind (Tamarindus indica L.). Southampton: International Centre for Underutilized Crops.

Kumar, B. M., & Nair, P. K. R. (2004). The enigma of tropical homegardens. *Agroforestry Systems*, 61(1), 135–152.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Anthony, S. (2009). Agroforestree database: A tree reference and selection guide. World Agroforestry Centre.

Rao, M. R., Nair, P. K. R., & Ong, C. K. (1998). Biophysical interactions in tropical agroforestry systems. *Agroforestry Systems*, 38(1–3), 3–50.

Van Sangyan (ISSN 2395 - 468X) Vol. 12, No. 10, Issue: October 2025

Published by:

Impact Factor
SJIF: 2022-6.071

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