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Sarita Bodalkar
Department of Forestry,
College of Agriculture, IGKV
Raipur, Chhattisgarh, India

Correspondence
Sarita Bodalkar
Department of Forestry,
College of Agriculture, IGKV
Raipur, Chhattisgarh, India

The potential of *Melia dubia* in agroforestry system

Sarita Bodalkar

Abstract
Melia dubia (Malabar Neem), a fast-growing deciduous tree of the family *Meliaceae*, has gained prominence as a multipurpose agroforestry species in India and Southeast Asia. Owing to its rapid growth, short rotation cycle (4-8 years), and suitability for pulpwood, plywood, and timber industries, it is increasingly adopted in farm forestry and commercial plantation programs. This review synthesizes existing knowledge on its botanical characteristics, growth performance, propagation techniques, and economic potential. Studies report high productivity, with mean annual increments exceeding under favorable conditions, coupled with flexibility in spacing and intercropping options that ensure compatibility with a wide range of crops. *M. dubia* contributes to livelihood security by providing assured market returns, diversifying income through intercrops, and serving as an intermediate host in high-value crops such as sandalwood. Ecologically, it enhances soil fertility, sequesters substantial amounts of carbon and supports biodiversity, making it a climate-resilient species. However, challenges such as high water demand during early growth stages, site-specific management requirements, and dependence on industrial markets remain constraints to large-scale adoption. Overall, *M. dubia*-based agroforestry systems present a climate-smart, economically viable, and environmentally sustainable land-use option with strong potential for expansion in India's agroforestry landscape.

Keywords: *Melia dubia*, agroforestry, short rotation forestry, carbon sequestration, intercropping, livelihood security, sustainable land use

Introduction
Agroforestry has emerged as a sustainable land-use system that integrates trees with crops and livestock, offering multiple ecological, economic, and social benefits. In India, where rising demand for timber, pulpwood, and plywood exerts pressure on natural forests, the adoption of fast-growing multipurpose tree species has become a vital strategy for meeting industrial needs while supporting smallholder livelihoods (Dhyani, 2014) [6]. Among the promising candidates, *Melia dubia* Cav., commonly known as Malabar Neem or Forest Neem, has gained attention as a short-rotation, high-yielding tree species suitable for diverse agroforestry systems. Belonging to the family *Meliaceae*, *M. dubia* is native to South and Southeast Asia and is characterized by its straight bole, rapid juvenile growth, and adaptability to varied agro-climatic zones (Chavan *et al*., 2015) [1]. Studies report mean annual increments exceeding 40 m^3 ha^{-1} yr^{-1} under favorable management, making it highly competitive with traditional industrial wood species such as *Eucalyptus* and *Casuarina*. The species thrives in mixed, block, and boundary plantations, while its relatively light canopy permits successful intercropping with cereals, pulses, spices, and vegetables during the early years of establishment. Beyond its economic significance, *M. dubia* contributes to ecosystem services such as soil fertility enhancement through litter deposition, carbon sequestration estimated at 12-15 t C ha^{-1} yr^{-1}, and landscape restoration on degraded lands (Montagnini & Nair, 2004) [5]. The species is increasingly integrated into climate-smart agroforestry models in states such as Tamil Nadu, Karnataka, Maharashtra, and Chhattisgarh, where contract farming and assured industrial markets further strengthen its adoption. Despite these advantages, challenges remain in optimizing water use, refining management practices such as pruning and thinning, and stabilizing market linkages to ensure equitable benefits for farmers. A systematic review of *M. dubia* in agroforestry is therefore timely to assess its biological potential, economic viability, and ecological benefits, while also identifying research and policy interventions required to promote its large-scale adoption.

Botanical and Ecological Characteristics of *Melia dubia*

Melia dubia Cav. (Malabar Neem), belonging to the family *Meliaceae*, is a fast-growing deciduous tree native to South and Southeast Asia. It typically grows 15-20 m tall (up to 30 m) with a straight bole, spreading crown, and bipinnate to tripinnate leaves. The species bears small, fragrant, greenish-white bisexual flowers in panicles, and fruits are ovoid drupes that ripen yellow, containing up to five seeds (Chavan *et al*., 2015; Agritech TNAU) [1]. Phenologically, leaf fall occurs between February-March, flowering from January-March, and fruiting between November-February, aligning well with cropping calendars. Ecologically, *M. dubia* is highly adaptable, thriving in a wide range of soils and rainfall regimes (600-2500 mm), though it requires adequate soil moisture in its early stages. The species provides significant ecosystem services, including soil fertility improvement**,** microclimate regulation**,** and carbon sequestration (12-15 t C ha^{-1} yr^{-1}). Its relatively open canopy supports intercropping with cereals, pulses, vegetables, and spices, while it also serves as a host for high-value crops like sandalwood and dragon fruit. These traits highlight its strong potential in agroforestry systems.

Propagation and Cultivation Practices

Melia dubia can be propagated both through seeds and clonal methods, though clonal propagation is increasingly preferred for producing uniform and high-quality planting material. Seed germination is generally good, but seedlings show variability in growth and wood traits. The development of mini-clonal and cutting techniques by research institutes such as FC&RI (Mettupalayam) and ICAR-CAFRI (Jhansi) has enabled large-scale, cost-effective multiplication of elite genotypes, with higher survival and success rates. Planting is usually carried out in the monsoon season (June-July) in pits of 45 × 45 × 45 cm, filled with a mixture of farmyard manure, neem cake, and basal fertilizers. Regular watering during the initial two years and periodic fertilizer applications (N:P:K @ 19:19:19) are recommended to promote early growth. Application of fungicides (e.g., Bavistin) and insecticides (e.g., chlorpyrifos) at planting helps protect young seedlings from soil-borne pathogens and termite damage. Spacing depends on the end use: closer spacing (3 × 1.5 m to 3 × 2 m) favors pulpwood production due to higher stand density, while wider spacing (4 × 4 m or more) is recommended for plywood and timber**,** as it encourages better bole development and allows intercropping.

Agroforestry Potential and Intercropping Systems

Melia dubia has emerged as a highly compatible tree species in agroforestry owing to its rapid growth, light canopy, and straight bole**,** which allow sufficient sunlight penetration for intercrops during the initial years of establishment. Its relatively open crown architecture makes it suitable for a range of agroforestry models, including boundary planting, block plantations, silvo-pastoral systems, and alley cropping (Chavan *et al*., 2015) [1]. Research and field studies have shown that *M. dubia* can be successfully intercropped with cereals (maize, sorghum), pulses (black gram, green gram, cowpea), oilseeds (groundnut, sesame), and vegetables (brinjal, chillies, okra, onion) during the first 3-4 years before canopy closure. Longer-duration crops such as turmeric, ginger, and medicinal plants also perform well under wider spacing regimes (4 × 4 m and above). Due to its multipurpose uses like bioenergy production, paper and pulp manufacturing, furniture making, building constructions, making musical instruments etc., it is gaining more popularity and is in high demand (Suprapti *et al*., 2004; Parthiban *et al*., 2009; Chinnaraj *et al*., 2011) [3, 4, 7]. Beyond food crops, *M. dubia* is also used as a host tree for sandalwood (*Santalum album*) and as a shade tree in dragon fruit orchards, particularly in Maharashtra and Karnataka. Silvo-pastoral trials have demonstrated its compatibility with fodder grasses, offering additional benefits for livestock integration. Such versatility makes it a climate-smart species capable of enhancing farm incomes while supporting industrial raw material supply. The agroforestry potential of *M. dubia* is thus defined by its short rotation cycle (5-8 years), assured industrial demand, and compatibility with diverse crops, making it a preferred species for both smallholder farmers and commercial agroforestry ventures in India.

Economic Importance

Melia dubia is considered one of the most profitable short-rotation tree species in India due to its high biomass yield (80-250 t ha^{-1} in 4-8 years**)** and strong industrial demand. It is widely used for pulpwood, plywood, timber, and fuelwood**,** with farmers earning assured returns through buy-back arrangements with paper and plywood industries. Case studies indicate net benefits exceeding ₹1.1 million ha^{-1} with a benefit-cost ratio of 1:3.9 under agroforestry models. In addition, its compatibility with intercrops provides dual income streams, making it an economically viable option for both smallholders and commercial plantations.

Environmental significance

Melia dubia plays a vital role in enhancing ecosystem services within agroforestry systems. Its fast growth and litter deposition improve soil organic matter and fertility, while the species contributes substantially to carbon sequestration (12-15 t C ha^{-1} yr^{-1}) and land restoration on degraded sites. Its relatively open canopy supports intercrop diversity**,** regulates microclimates, and provides habitats for biodiversity, making it a climate-smart and ecologically sustainable tree species (Montagnini & Nair, 2004) [5].

Future Prospects and Research Needs

Melia dubia has strong potential as a climate-smart, short-rotation species to meet industrial wood demand while supporting farmer livelihoods. Future prospects include its integration into carbon markets, bioenergy, and land restoration programs. Research is needed on genetic improvement, water-use efficiency, and long-term tree-crop interactions, along with reliable carbon accounting methods. Policy support, market linkages, and farmer extension will be crucial for scaling adoption and realizing its full agroforestry potential.

Conclusion

Melia dubia has emerged as a promising agroforestry species due to its fast growth, short rotation, and high economic returns, while also contributing to soil health, carbon sequestration, and biodiversity support. Its compatibility with diverse intercrops provides farmers with dual income opportunities and strengthens livelihood security. With proper management, policy support, and market linkages, *M. dubia* can play a vital role in promoting

sustainable agroforestry systems and meeting future industrial and ecological demands.

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