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Pre-sowing treatments, dormancy, and seed germination behavior in *Melia azedarach*: A Review

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Abstract

Melia azedarach is a deciduous tree species of the Meliaceae family that grows quickly and is found throughout tropical and subtropical areas. The species is prized for its lumber, pesticidal, decorative, and medicinal qualities. While its wood is used to make pulp, furniture, packing boxes, and musical instruments, other plant parts like leaves, bark, roots, fruits, and seeds are traditionally used to treat a variety of illnesses. *Melia azedarach* seed germination is a complicated physiological process that is impacted by both internal and external variables. Due to its stiff seed coat and endocarp, which limit gaseous exchange and water absorption, the species frequently displays physical dormancy. Imbibition is the first step of germination, which is followed by radicle emergence and metabolic activation. Scarification, hot water treatment, cold stratification, sulphuric acid treatment, and gibberellic acid application are some of the pre-sowing techniques that work well to increase germination. Growth regulators, temperature, moisture, light, oxygen, and seed maturity all have a big impact on germination and seedling establishment. Gibberellins and other hormones encourage germination, but abscisic acid preserves dormancy. Improving nursery methods, afforestation programs, and the creation of large-scale plantations of this economically significant forest tree species requires an understanding of seed dormancy, germination behaviour, and appropriate pre-sowing treatments.

Keywords: Seed dormancy, seed germination, pre-sowing treatments, scarification, stratification

Introduction

Chinaberry, or *Melia azedarach* L., is a deciduous tree species that grows quickly and belongs to the Meliaceae family. And grows naturally up to an elevation of 1800 meters above sea level. The species is distinguished by its purplish flowers, fragrant leaves, and green fruits that turn yellow when they ripen (Mahood and Sarropoulou, 2024) [73]. Mature trees have huge, bi- and tri-pinnate, fluffy leaves that can grow up to 90 cm in length, an umbrella-shaped crown, and a maximum height of 25 m. It grows best on low-acid, rich, well-drained soils (Singh *et al.*, 2020) [74]. Seed germination and seedling growth are influenced by the age of the seed. Seed germination and growth occur in mature seeds. Seed germination increased with an increasing collection period (Netam *et al.*, 2025) [45]. To improve germination and seedling vigour, presowing treatments such as KNO₃, GA₃, and H₂SO₄ are essential. These methods help overcome dormancy and promote faster, more uniform germination. Gibberellic acid (GA₃) is a plant growth regulator that enhances germination and seedling elongation by stimulating α amylase activity and promoting cell expansion (Rout *et al.*, 2017) [75]. Soaking seeds in 500 ppm GA₃ for 120 minutes significantly improved germination in *Bauhinia purpurea* (Deepu Mathew and Siva Kumar, 2002) [77]. Similarly, acid scarification with concentrated H₂SO₄ for 10 minutes improved germination in *Ziziphus mauritiana* (Rajwade *et al.*, 2025) [50]. There are three different species of *Melia*: *Melia dubia*, *Melia composita*, and *Melia azedarach*. In 2019, Parthiban *et al.* [72]. The tree *Melia azedarach* is deciduous (Troup, 1921) [71]. Seed germination is a complex process that leads to the resumption of active growth in the embryonic axis, rupture of the seed cover and emergence of the young plants. For physiologists and biochemists, germination is complete when the radicle ruptures and the cover becomes visible. For seed technologists, foresters, nursery growers, etc., however, germination is a complex process that leads to the resumption of active embryonic growth and continued growth and development until

a potentially independent seedling is formed (Bargah *et al.*, 2025) ^[8]. Nurseries provide the means to control moisture, light physical and chemical soil constituents in such a way as to produce healthy and uniform seedlings for planting. Several factors can influence seedling growth in the nursery (Nishad *et al.*, 2025) ^[46]. Plants are propagated and grown to a size that can be planted in a nursery. A quality nursery stock is necessary to create a good plantation. The necessity of forest nurseries in order to properly nurture seedlings before planting them on land that needs to be replanted (Verma *et al.*, 2024) ^[67]. Seedlings are small plants with enough potential to grow into mature trees. These seedlings grow naturally, but they can also be propagated by seeding and germinating, which helps them to sprout quicker and boost their chances of survival. The factors must be optimal to produce a healthy and vigorous seedlings, and among them, the genes and the nursery environment determine to a large degree how a tree can survive (Minj *et al.*, 2024) ^[41]. Agroforestry is a comprehensive term encompassing land-use systems where woody perennials like trees, shrubs, and bamboos are cultivated alongside herbaceous plants such as crops, pasture, and/or livestock. These elements are organized spatially or temporally, facilitating ecological and economic interactions between the tree and non-tree components. The principal constituents of agroforestry systems include trees, shrubs, crops, pastures, and livestock, along with factors like climate, soil, and the surrounding environment (Bargah *et al.*, 2024) ^[7, 9]. The *Melia azedarach* plant is well known for its striking cluster of pale purplish spreading flowers as well as the shade it provides in the summer thanks to its dense, dark, emerald leaves. *Melia azedarach* is a lovely avenue and shade tree in plantations and is sometimes planted as an ornamental tree. The bakayan tree is also referred to as the bakain tree, mahanimb in Hindi, Persian lilac in English, and Paradiso in South Africa. The entire Bakayan plant, including the leaves, stem, and roots, has a unique therapeutic quality. *Melia azedarach* shrubs range in size

from small to large, reaching heights of 5 to 15 meters. It is primarily found in tropical and subtropical regions, is closely related to neem, and has phytochemical components that are used to control pests. Malaria, diabetes, cough, skin conditions, bronchitis, leprosy, and asthma have all been treated with the many parts of *Melia azedarach*, including leaves, flowers, seeds, fruits, roots, bark, and stems. (Vijayanand, 2011) ^[76]. It engages in a variety of activities (Kumar & Singh, 2003). It has become a desirable raw resource because of its extraordinary strength and capacity to produce high-quality pulp. The *Melia azedarach* tree, which grows quickly and is frequently planted next to roads, is well-known for its decorative properties. Toys, small boxes, sporting goods, packing boxes, musical instruments, and museum cases are just a few of the uses for the wood that comes from this tree. Because of its productivity, it is also favoured for making saws and shuttles (Shukla and Bhatnagar, 1988). Furthermore, 40% of the seed yield's oil can be used for lighting (Singh, 1995) ^[58, 78].

Seed Germination

The first stage of a plant's life cycle is seed germination, which starts when a dry, dormant seed absorbs water and ends when the radicle emerges from the seed coat (Nonogaki *et al.*, 2010) ^[48]. It is a multi-step process. The process begins with seed imbibition (water uptake by seed), activation of plant metabolic enzymes, seed coat rupture, and finally the development of roots, shoots, leaves, and other plant organs (Bewley, 1997) ^[14]. According to Miransari and Smith (2014) ^[42], seed germination is a complicated process that incorporates multiple signals and is impacted by both internal and extrinsic influences. Extrinsic elements include water, temperature, oxygen, light, relative humidity, chemicals in the seed environment, and substrate used; intrinsic aspects include seed dormancy and accessible food stores (Bhardwaj, 2014; Makena *et al.*, 2018; Savaediet *et al.*, 2019) ^[37, 54].

Table 1: Seed germination can be divided into three phases corresponding to the phases of water uptake

Phase:1	Imbibition	Dry seeds quickly absorb water through imbibition, which initiates germination and revitalises embryo growth. Seed composition, seed coat permeability, and moisture availability are the primary determinants of water absorption.
Phase:2	Lag Phase	Imbibition reduces the amount of water absorbed, and metabolic functions like transcription and translation are restarted. The radicle separates from the seed coat as the embryo grows.
Phase:3	Mobilization of Reserve Food	As cells start to loosen and expand during embryonic growth, water uptake increases quickly. Cell wall relaxation and active cell enlargement sustain this ongoing water absorption.

Types of seed germination

Epigeal germination

During epigeal germination the cotyledons are raised above the ground where they continue to provide nutritive support to the growing points and during root establishment, the hypocotyls begin to elongate in an arch that breaks through the soil, pulling the cotyledon and the enclosed plumule through the ground the projecting them into the air. Afterwards the cotyledons open, plumule growth continues and the cotyledons wither and fall to the ground. (Bewley *et al.*, 2013; Taiz *et al.*, 2015) ^[15, 63].

Example

- *Melia azedarach* (Bakain)
- *Azadirachta indica* (Neem)
- *Tectona grandis* (Teak)
- *Dalbergia sisso* (shisham)

Hypogeal germination

During Hypogeal germination, the cotyledons or comparable storage organs remain beneath the soil while the plumule pushes upward and emerges above the ground in this germination the epicotyl is the rapidly elongating structure. Regardless of their above-ground locations, the cotyledons or comparable storage organs continue to provide nutritive support to the growing points throughout germination (Bewley *et al.*, 2013; Taiz *et al.*, 2015) ^[15, 63].

Example

- *Terminalia catappa* (tropical almond)
- *Quercus* spp (oak)
- *Shorea robusta* (sal)

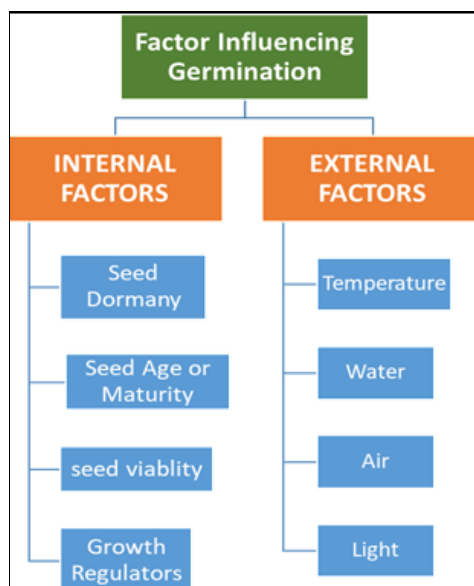


Fig 1: Factors influencing seed germination

Internal factors

Seed dormancy: The physiological state known as "seed dormancy," which prevents a viable seed from germinating even in favourable conditions ((Umarani and Vanangamudi, 2005) [65], varies. Seeds lose viability quickly, but others can be kept for several months. When water seeps through the seed coat, which causes swelling and subsequent plant growth, seeds, which consist of an exterior protective coat and an inner embryo growing into the plant, begin to germinate (Reddy *et al.*, 2022) [79].

Seed age or maturity: The age of the seed has an impact on seed germination and seedling growth. Mature seeds undergo germination and growth (Singh and Singh, 1992) [59]. As the collection duration grew, so did seed germination. Fruits harvested 20 to 40 days following fruit maturity had a high germination rate. For *Melia azedarach* seed collection in the field, color change (from green to yellowish-brown) is regarded as a crucial indicator. Freshly picked *Melia azedarach* fruits frequently germinate poorly, while older or stored fruits do better. According to studies, one year-old fruits germinate more readily than fresh fruits.

Table 2: Types of Dormancies

Physiological Dormancy	Physiological dormancy, which is mostly seen in species like eucalyptus, pine, and fagus, is triggered by the embryo or the surrounding endosperm tissues. Non-deep physiological dormancy in freshly grown seeds prevents them from germinating at any temperature or restricts their germination to a specific temperature range.	Reddy <i>et al.</i> , 2022 [79]
Morphological Dormancy	Morphological Dormancy are Underdeveloped embryos in seeds that need time to mature and germinate.	Umarani and Vanangamudi, 2005 [65]
Physical Dormancy	A layer of thick-walled, cutinized, palisade-like macroscleroid cells makes seed coverings water-impermeable. To encourage germination in water-impermeable seed coverings, a variety of techniques are used, including as chemical and mechanical scarification or soaking in boiling water. Applications for water-permeable seed coverings include scarification, heat treatment, gibberellic acid (GA3) or sodium hypochlorite treatment, and cold stratification.	Savage and Metzger, 2006

Table 3: Dormancy and Pre-soaking treatments in *Melia* genus to improve germination

S no.	Species	Dormancy type	Treatment	Reference
1	<i>Melia azedarach</i>	Physical	Cow dung slurry for 30 days	Ananndet <i>et al.</i> , 2012
2	<i>Melia azedarach</i>	Physical	Cold water treatment at 4 degree for 12 hours	Azad <i>et al.</i> , 2006
3	<i>Melia azedarach</i>	physical	Hot water treatment at 80 degree for 10 minutes	Ebeid <i>et al.</i> , 2022 [22, 23]
4	<i>Melia azedarach</i>	Physical	Concentration H ₂ SO ₄ For 10 minutes	Khaiperet <i>et al.</i> , 2023
5	<i>Melia azedarach</i>	Physical	Seeds are soaked in GA ₃ Concentration of 200,300,500 PPM for 24 hours	Cavusoglu and Sulusoglu, 2019 [17]
6	<i>Melia azedarach</i>	Physical	Sandpaper Scarification	Azad <i>et al.</i> , 2010 [4]

This could be because the fruits are subject to natural weathering processes. Fresh fruits may have poor germination because of their hard endocarp and seed coat, which limit gas exchange and water absorption. A post-ripening procedure is frequently necessary for seeds like *Melia azedarach*, which may show a modest level of physiological dormancy or immaturity. These seeds experience certain chemical and physical changes when being stored in dry circumstances. Biochemical changes including the decrease of stored lipids and carbohydrates take place during storage. Gibberellin synthesis and protein hydrolysis are also Encouraged. In the end, more metabolic activity promotes seed Germination (Holdsworth *et al.*, 2008) [29, 30].

Techniques for overcoming seed dormancy/ pre-sowing

treatments to break seed dormancy: Seed priming involves a regulated treatment before sowing that allows for partial hydration or biochemical activation of seeds without triggering radicle growth. Traditional priming methods are widely used to break seed dormancy, promote more uniform germination, boost seedling growth, and increase resistance to non-living environmental stresses. These techniques are typically inexpensive and simple to implement; however, their success hinges on seed physiology, treatment duration, and scalability. Pre-treatment strategies are essential for overcoming seed dormancy, enhancing seedling growth, reducing antinutritional factors, and improving both nutrient production and accessibility. The pre-treatment needed varies depending on the species, harvesting conditions, and seed characteristic

Table 4: Various seed treatment methods and their mechanisms for breaking dormancy and enhancing seed germination

Treatment	Definition/ Process	Author
Scarification	Scarification, either mechanical or chemical, helps break physical dormancy in hard-coated seeds by improving water and air entry. Methods such as nicking, soaking, or removing the endocarp are commonly used to enhance germination in species like <i>Acacia</i> , <i>Terminalia</i> , and <i>Melia azedarach</i> .	Doran <i>et al.</i> , 1983; Tietemaet <i>et al.</i> , 1992; Hossain <i>et al.</i> , 2005 [21, 31, 64]
Scarification Chemical Scarification	Acids like H ₂ SO ₄ , HCl, or KNO ₃ are used in chemical scarification to break dormancy and weaken hard seed coats, improving gas exchange and water absorption. By encouraging embryo growth, these treatments help soften the hard endocarp and enhance germination in species such as <i>Melia azedarach</i> .	Jaganathan <i>et al.</i> , 2019; Jin <i>et al.</i> , 2023
Pre-Chilling (Cold Stratification)	To break dormancy and promote germination, seeds are stored in moist conditions at low temperatures (3-5°C) for one to two weeks. For efficient seed germination, cold-adapted species typically need significantly lower temperatures and longer stratification times.	Cuena-Lombrana <i>et al.</i> , 2018 [19]
Hormonal Treatment	To break seed dormancy and enhance germination, plant hormones like ABA, ethylene, jasmonic acid, and particularly gibberellic acid (GA ₃) are utilised. GA ₃ treatment helps the seedling break through the seed coat, softens the endosperm, and encourages embryo growth.	Shu <i>et al.</i> , 2016 [56]
Hot or Cold-Water Treatment	Simple treatments that soften hard seed coats, such as soaking seeds in water and exposing them to heat, are low-cost ways to enhance germination. According to studies, dormancy can be effectively broken and seed sprouting improved by combining heat treatment, acid scarification, or soaking for 24-48 hours.	Kontchoiet <i>et al.</i> , 2020

Seed viability: The ability of a seed to survive and produce a healthy seedling under ideal conditions is known as seed viability, and it is a crucial component of successful germination. Viable seeds have intact cellular architecture, functional enzymes, and sufficient stored reserves to support early metabolic processes. The stage of seed maturity at harvest and the degree of viability are closely related; seeds collected at physiological maturity usually exhibit maximum viability due to full embryo development and accumulation of storage compounds, whereas immature seeds often exhibit poor germination and decreased survival (Bewley *et al.*, 2013; Copeland & McDonald, 2001) [15, 18]. One of the main causes of seed viability loss during storage is seed ageing. Membrane degradation, lipid peroxidation, enzyme inactivation, and the build-up of reactive oxygen species are all signs of the cumulative deterioration that seeds experience over time, all of which reduce metabolic efficiency and germination potential.

Environmental factors, especially temperature and moisture content, have a significant impact on the rate of this degeneration. According to McDonald (1999) [40] and Walters (1998) [68], seeds stored at high humidity and temperature quickly lose their viability, whereas those kept at low temperatures and under controlled moisture conditions do so for longer. The way seeds are stored also affects how much vitality can be maintained. While refractory seeds are vulnerable to drying and quickly lose viability, orthodox seeds, which are found in many forest species, may withstand desiccation and be stored for long periods of time under the right circumstances. Sustaining viability requires maintaining biochemical integrity, which includes membrane stability and enzyme activity. High seed viability is essential for consistent germination, good seedling establishment, and efficient regeneration in forestry techniques; therefore, appropriate harvesting, handling, and storage are essential (Roberts, 1973; Bewley *et al.*, 2013) [15, 52]

Table 5: Growth regulators

Growth Regulators	Definition/Process	Author
Auxin	Auxins, particularly Indole-3-acetic acid (IAA), are essential plant hormones that control seed development, cell differentiation, root initiation, and overall plant growth by coordinating gene expression. Auxins are crucial for both plant growth and vegetative propagation because of their interaction with gibberellins and abscisic acid, which controls seed dormancy and germination.	Matilla, 2020; Figueiredo & Köhler, 2018 [24, 39]
Gibberellic Acid	Gibberellins (GAs) are crucial plant growth regulators that help break seed dormancy by increasing radicle emergence, hydrolytic enzyme activity, and embryo elongation. While GA signalling via the GID1-DELLA pathway and environmental factors like temperature control germination responses in many forest species, the balance between GA and abscisic acid plays a major role in controlling seed germination	Bewley <i>et al.</i> , 2013; Nonogaki, 2014 [15, 47]
Absciscic Acid	A significant plant hormone called abscisic acid (ABA) suppresses embryo growth, controls dormancy-related gene expression, and prevents premature germination under unfavourable circumstances to induce and maintain seed dormancy. The equilibrium between gibberellins and ABA regulates seed germination, and environmental elements like moisture, light, and temperature affect ABA signalling and metabolism in many forest species.	Seo <i>et al.</i> , 2009; Nonogaki, 2014 [47, 55]

Table 6: External Factors

External Factor	Process	Author
Temperature	Seasonal variations in temperature have an impact on seed germination by controlling the temperature conditions necessary for germination as well as the release of dormancy. While germination of non-dormant seeds depends on their minimum, optimum, and maximum temperature limits, different species require warm or cold stratification periods.	Baskin & Baskin, 2014; Sousaraei <i>et al.</i> , 2021 [10]
Water	Water availability influences seed germination by controlling water uptake and dormancy behaviour; adequate moisture promotes germination, whereas dry conditions may cause secondary dormancy.	Soltani <i>et al.</i> , 2021; Ramos & Valls, 2019 [51, 60]

	Waterlogging for a brief period can promote germination, but prolonged flooding lowers metabolic activity, produces an oxygen shortage, and may postpone germination or kill seeds.	
Air (O ₂ & CO ₂)	While low oxygen levels can prevent germination, oxygen is necessary for seed germination because it promotes the increased respiratory activity required for embryo growth. While nitrogen typically has little effect on germination, high carbon dioxide concentrations inhibit the process.	Zhou <i>et al.</i> , 2005 ^[70]
Light	Light affects seed germination differently across species, with some seeds requiring light and others germinating better in darkness, and these responses are frequently influenced by temperature and dormancy status. The phytochrome system regulates this process by sensing red and far-red light, which influences hormonal activity and germination timing.	Baskin & Baskin, 2003; Mathews, 2006 ^[38]

Conclusion

A significant multipurpose forest tree species, *Melia azedarach* is prized for its quick growth, therapeutic benefits, aesthetic appeal, and ability to produce high-quality lumber. Effective seed germination and dormancy control are critical to the species' successful proliferation. Under natural circumstances, the hard seed coat and endocarp frequently induce physical dormancy, which lowers the germination rate. Scarification, soaking, hormone therapy, and stratification are a few pre-sowing techniques that help break dormancy and improve seedling establishment. Germination is mostly controlled by external elements like temperature, water, oxygen, and light, as well as internal elements like seed viability, maturity, and plant hormones. Among the regulators of plant growth, while abscisic acid preserves dormancy, gibberellins promote germination. Enhancing nursery production, afforestation, and sustainable use of *Melia azedarach* requires a thorough understanding of these physiological and environmental factors. Large-scale plantation programs can be supported, and germination success greatly increased with the use of appropriate seed handling and treatment techniques.

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