

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(8): 2349-2355
www.biochemjournal.com
Received: 08-06-2026
Accepted: 14-07-2026

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Comparative evaluation of pre-sowing seed treatments on seed germination and seedling growth of *Acacia catechu*

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8Sz.9758>

Abstract

Acacia catechu Wild (Fabaceae). is an economically and ecologically significant deciduous tree of South Asian origin, valued for its heartwood-derived catechin, medicinal properties, tanning compounds, timber and contribution to agroforestry systems across South and Southeast Asia; however, seed dormancy and poor germination remain major constraints to its successful propagation and establishment. The primary objective of this review is to provide a comparative analysis of various pre-sowing seed treatments and their effects on seed germination and seedling growth, with particular emphasis on *Acacia catechu*. Various physical and chemical seed treatments, including hot water soaking, mechanical scarification, sulfuric acid (H_2SO_4), and growth regulators such as gibberellic acid (GA_3), have been described to improve seed germination and improve seedling growth characteristics. Comparative study of the reviewed studies indicates that the effectiveness of these treatments varies among species and environmental conditions.

Keywords: *Acacia catechu*, pre-sowing seed treatments, seed dormancy, growth parameter, scarification

1. Introduction

Acacia catechu Khair is a medium-sized tree of the Fabaceae family, known by many other names, such as catch Katha, and is widely spread in many states, such as Maharashtra, Tamil Nadu, and Andhra Pradesh. Khair is a multipurpose tree used for medicinal purposes, and in ancient times, it was considered an important place in Ayurveda. (Imran and Shaikh 2025) ^[1] It has been used for the treatment of diseases for a long time now. The wood bark of Khair (*Acacia catechu*) is used to treat diseases. Its heartwood contains a substance called Katha, which has many chemical properties, such as tannins, catechins, and flavonoid compounds. (Agravat *et al.*, 2025) ^[2] Traditional medicinal uses of *Acacia catechu* are a multi-purpose tree that is highly valued for its medicinal properties. This plant has long been utilized in traditional medicine and Ayurveda, particularly in Asia, for its valuable nutritional attributes. In Ayurveda, Sidney (Stohs and Bagchi, 2015) ^[3] there are many references that prove that *A. catechu* is a beneficial and potent plant with many medicinal properties, including the treatment of skin diseases; hence, (Kumari *et al.*, 2022) ^[4]

A. catechu plant has been used to treat a variety of diseases, especially asthma, bronchitis, cancer, chest pain, diarrhea, mouth ulcers, sore throat, ulcers, vitiligo (white spots), and wound healing. It also has antifungal, antiviral, and spasmolytic properties, as well as hypoglycaemic properties. (Adhikari *et al.*, 2021) ^[5] Khair bark contains chemical properties such as alkaloids and several other highly potent active components that exhibit antimicrobial activity; therefore, it also acts as a disinfectant for the management of wounds and burns, thereby reducing the chances of infection at the wound site. (Yadav *et al.*, 2019) ^[6] Due to the presence of alkaloids and other active components in Khair, it is used to treat various dermatological diseases. Traditional healers in Rajasthan and Gujarat (India) apply a paste of *Acacia catechu* wood powder (mixed with honey) to peripheral areas, especially in cases involving the lower limbs. It is an Ayurvedic remedy for treating diabetes. (Mishra *et al.*, 2025) ^[7]

The medicinal uses of *A. catechu* are mainly due to its outer covering and the extract obtained from its 'heartwood' (inner hard part of the tree trunk) (called catechu or ketch), which also has a variety of chemical properties and is known to be rich in bioactive compounds. However, the astringent, antimicrobial, anti-inflammatory, and antioxidant properties of *A. catechu* have been studied extensively. (Binita and Gupta 2023) [8] The Khair tree is primarily utilized as firewood and fuel wood, as well as for the production of charcoal. Additionally, it is employed as timber for constructing house frames, windows, and doors, and for crafting agricultural tools. (K.N. Singhand Brij Lal 2006) [9] *Acacia species* promote soil conservation because their roots reach deep, helping to prevent soil erosion, especially in sloping areas. Therefore, they are used in areas with steep slopes to prevent soil erosion. (Sourabh *et al.*, 2023) [10] *Acacia catechu* play an essential role in maintaining forest productivity and biodiversity a leguminous tree species, it forms symbiotic relationships with nitrogen-fixing bacteria, which increases soil fertility and enhances nutrient cycling (Koutika *et al.*, 2019) [11]. Khair has long roots that prevent soil erosion, so it is especially cultivated in poor and sloping areas. It is a drought-tolerant species that can survive in arid and semi-arid areas, making it easily cultivated in drought-prone areas. It helps in carbon sequestration. It absorbs carbon dioxide from the atmosphere and stores it, helping to mitigate the effects of climate change. Its trees, plants, birds, and other creatures provide habitat and food, thereby supporting biodiversity. (Kumar *et al.*, 2022) [12] Trees of this family are used in land restoration. They help rehabilitate unfertile and damaged land because they grow easily even in low-fertility soils. Therefore, they are planted in areas that have become unproductive or where no other tree species can grow. This species is planted in such areas to protect the area (Patil *et al.* 2024) [13] Forest species, such as *Acacia catechu*, suffer from significant seed dormancy problems. This is usually due to the hard seed coat, which prevents water from penetrating inside, causing it to go into dormancy. The proper temperature is crucial for the germination of Khair seeds. Occasionally, seeds require lighter to germinate. Several techniques are adopted to promote good germination in Khair, such as sulfuric acid treatment, hot water treatment, and mechanical saccharification. (Mulik Abbaker Ibrahim Yousif. 2019) [14]

2. Materials and Methodology

The present review was conducted through a of *Acacia catechu*, is based on an overview of the published scientific literature related to seed treatments of *Acacia catechu*, including their effects on various growth parameters and seed germination research paper for study: Information has been obtained from review articles, dissertations, technical reports and books. For this, I have obtained information from online sources like Google Scholar, Research Gate, Science Direct Scoops and Web of Science.

3. Botanical Description

3.1 Tree Morphology

Acacia catechu is a medium-sized tree of the Fabaceae family commonly known as black catechu, is derived from the Greek word "thorns," which means sharp or thorny. (Rout *et al.*, 2021) [15] It is a medium-sized tree that grows up

to 15 m tall. It has brown bark, 12-15 mm thick, and a curved, thorny trunk, approximately 30-40 cm long. Its branches were irregularly shaped (Ahmed, M. A.2020) [16]. Contributing to its characteristic appearance There are thorns on every branch of the Khair tree. (Sangare *et al.*, 2026) [17]

3.1.1 Leaves (phyllodes)

Leaves are compound, with 4-5 small spines on the main stem. The leaf branches are approximately 10-20 cm long and bear 20-60 small leaflets, each 3-3 cm long. The leaves are compound and bipinnate, with 9-30 pairs of pinnate leaves, each pair having 16-50 pairs of glabrous, oblong, pubescent, 2-6 mm long leaflets, and bearing pairs of curved spines. The flowers are borne on an axillary spike 5-10 cm long and range from creamy to pale yellow. (Binita *et al.*, 2023) [8] (Singh *et al.*, 2025) [18]

3.1.2 Flowering Phenology

Acacia catechu flowers seasonally, naturally during the monsoon of June-August. The flowers are small, pale yellow to creamy white, (Thakur *et al.* 2025) [18] and borne in axillary spike 5-10 cm long and range Flowering is influenced by environmental factors such as rainfall, temperature and photoperiod. Pollination is primarily entomophilous, involving a variety of insects. Flowering is followed by fruiting, and the pods ripen after the monsoon and during the winter season yellow (Rahaman *et al.* 2022) [19]

3.1.3 Inflorescence and Fruits

Acacia catechu flowers are slender axillary spikes containing numerous small, bisexual flowers. These spikes typically arise from the leaf axils and are densely packed with flowers. The flowers typically bloom during the monsoon season, allowing for good insect pollination. The fruit is pod-shaped, approximately 5-7 cm long and 1-1.5 cm wide, and is a shiny brown colour. (Khandekar *et al.*, 2019) [20]

3.1.4 Seed Characteristics

Acacia catechu seeds are small, with a hard coating, dark brown to black in colour, and enclosed within flattened pods, 10-15 cm long. Seed characteristics such as seed size, weight, viability, and germination behaviour vary significantly across seed sources and geographical locations. The hard seed coating induces physical dormancy, preventing the seeds from germinating quickly. Pre-treatment methods such as hot water soaking or acid soaking and scarification are often required to enhance germination. (Jhila *et al.*, 2018), (Ahad, and Varghese 2020) [21,22]

4. Habitat

Acacia catechu is a tropical and subtropical deciduous tree found at altitudes of 200-1200 m above sea level. It grows well in hot and dry climates and is cultivated worldwide. (Sangare *et al.* 2026) [17] These drought-tolerant trees do well in well-drained loam soil, which is considered the most suitable for their growth. Khair plantations are spread over approximately 5,800 square kilometres of land across the country. Every year, about 63,000 tonnes of khair wood is used to make catechu. (Imran and Shaikh 2024) [1]

5. Seed Dormancy

Seed dormancy, a physiological condition that prevents a viable seed from germinating even under good conditions (Umrani and Vannangamudi 2005) ^[23], shows significant variation in the storage time of different seed types. Approximately seeds can be stored for several months, while others lose their viability quickly. Consisting of an outer protective layer and an inner embryo that develops into a plant, seeds begin to germinate when water penetrates

the seed coat, causing swelling and subsequent plant growth. (Baskin and Baskin, 2004) which include sulfuric acid treatment and mechanical saccharification, but hot water treatment is considered to be the most effective. The seeds are soaked in hot water to soften them. Seed dormancy is divided into physical, morphological and physiological dormancy. These types are differentiated based on the severity of seed selection and embryo development, and internal physical barriers. (Ghassali *et al.* 2022) ^[24]

Table 1: Types of Seed Dormancy

S. N	Type of seed Dormancy	Description	Example/feature	Citation
1.	Physiological Dormancy	Physiological dormancy is primarily observed in species where it begins in either the embryo or the surrounding endosperm tissue. Freshly ripened seeds that do not have a long physiological dormancy period either cannot germinate at any temperature or germinate only within a limited temperature range.	species like Fagus, Pinus, and eucalyptus,	Reddy <i>et al.</i> , (2022) ^[25] Sarvade <i>et al.</i> , (2014) ^[26]
2.	Morphological dormancy	Dormancy occurs in some seeds, in which the embryo is not fully developed at the time of seed dispersal. If such seeds are planted immediately after harvest, they do not germinate.	Seed immature condition	Finch and Leubner (2006) ^[27]
3.	physical dormancy	In physical dormancy, the seed coat becomes so rigid that it cannot absorb water, and germination does not occur even when a suitable environment is available.	Mechanical scarification, chemical treatment, and boiling water soaking.	Carol C. Baskin, & Jerry M. Baskin1 (2005) ^[28]

5.1 Morphological Dormancy

Seed dormancy is a type of dormancy in which the embryo is not fully developed at the time of seed dispersal. Germination in these seeds requires embryonic development. Embryos require time to grow and develop before germination. Kumar *et al.*, (2024) ^[29] The embryo grows when conditions allow for favourable moisture and temperature, and then the seed germinates.

5.2 Physical Dormancy

Physical dormancy is a condition in which the seed does not germinate quickly due to its hard layer, which prevents it from absorbing water and thus prevents germination. Mechanical saccharification and hot water treatment are used to break down this layer. (Carol C. Baskin, & Jerry M. Baskin 2005)

5.3 Physiological Dormancy

Physiological dormancy is a type of seed dormancy in which biochemical or physiological factors that prevent germination are present in the embryo. In such seeds, the embryo is fully developed, and the seed coat absorbs water; however, germination does not occur due to internal physiological barriers. (Carol C. Baskin, & Jerry M. Baskin 2005)

6. Seed Treatment

Forest tree species often suffer from problems such as hard

seed coats, dormancy, low germination percentage, and uneven germination. To overcome these problems and increase the germination capacity of seeds, various types of seed treatments have been adopted before sowing (Kelil and Taye, 2026) ^[30]. Seed treatment is an important pre-sowing technique in which seeds are treated with physicochemical and biological methods to break dormancy and promote seed germination and produce healthy plants. (Hanaoka *et al.* 2014) ^[31] Seed treatment plays an important role in producing high-quality seedlings in forest nurseries. One of the most commonly used methods for forest species is hot water treatment, which includes techniques such as mechanical saccharification. In species with hard seed selection, hot water treatment and light scarification increase water absorption, leading to faster and more uniform germination (Patil *et al.*, 2012) ^[32]. Chemical treatments using H₂SO₄, GA₃, and KNO₃ were used. This treatment helps reduce seed hardness and increase embryo activity. Physical dormancy is common in forest species because of their hard seed coats. Hot water treatment, sulfuric acid cupping, and scarification have been shown to significantly increase the germination percentage of these species, inducing proper germination. Proper seed treatment not only increases germination but also improves the initial growth, survival rate, and nursery performance of seedlings. (Satti *et al.*, 2016) ^[33]

Table 2: Various pre-sowing treatment and their methodologies

S. N	Seed treatment method	Overview	Examples/result	References
1.	Soaking in Cold Water	Soaking seeds in cold water for 24 to 48 hours prior to sowing has been explored as an effective pre-treatment method	Use for <i>A. nilotica</i> <i>Albizia</i> , <i>Cassia</i> , <i>Poplars</i> and <i>Leucaena leucocephala</i>	Hossain <i>et al.</i> (2005) ^[34]
2.	Soaking in Hot Water	For seeds with hard coatings, soaking in boiling hot water has proven to be an advantageous method this treatment involves soaking seeds in hot water for 2-48 hours, depending on the species	Subabul seeds soaked in hot water for 12 hours exhibited a significantly increased germination percentage (42.22%)	(Hamad and Anwer, 2021) ^[35]
3.	Mechanical (Knuckling and Sand Paper Scarification)	Mechanical treatments play a crucial role in breaking the impermeable and hard seed coats of species Research indicates that knuckling the distal ends seeds enhance germination without causing damage to the embryo	<i>A. catechu</i> <i>A. nilotica</i> <i>Albizia</i> spp. The scarification of seeds from <i>Melia azedarach</i> <i>Acacia auriculiformis</i> Cunn. Benth with sandpaper resulted in impressive germination rates of 80% and 78%, respectively <i>Dalbergia sissoo</i> Roxb. achieving 100% and 90.4% germination, respectively	Alamgir and Hossain, 2005 ^[36] Chichaghare <i>et al.</i> , 2020 ^[37] Azad <i>et al.</i> , 2010 ^[38] Asif <i>et al.</i> , (2020) ^[39]
4.	Acid Scarification	Soaking seeds in concentrated sulphuric acid is a common method for softening the seed coat. Sulphuric acid is believed to disrupt the seed coat and expose the lumens of the macroscale's cells, facilitating water imbibition	<i>Acacia auriculiformis</i> seeds treated with concentrated H ₂ SO ₄ for 5-10 minutes exhibited the highest germination percentage of 92-96%. Studied concentrated H ₂ SO ₄ treatment in <i>Acacia cyanophylla</i> ; 90 min treatment at 15 °C resulted in 98.5% germination.	Olatunji <i>et al.</i> (2012) ^[40] Shaybany and Rouhani (1976) ^[41]
5.	Gibberellic acid (GA3)	Seed treatment with GA3 increases germination rates and stimulates enzyme activity, as well as promoting root and shoot growth.	followed by <i>Acacia auriculiformis</i> (54%), <i>Delonix regia</i> (47%), and <i>Cassia fistula</i> (33%).	Praticia <i>et al</i> (2023) ^[42]
6.	Beejamrutha	To prepare Beejamrutha 500 g. of fresh cow dung and 500 ml of cow urine are mixed, and 10 g. of lime are added to it.	This helps break seed dormancy and increases seed viability and vigour. The germination percentage increased to 55.93% with the Beejamrutha compared to 49.4% in the control.	Rahul <i>et al.</i> (2024) ^[43]
7.	Cow urine and cow dung slurry	Cow dung slurry and cow urine treatment breaks the dormancy of the seed and increases the germination percentage of the seed and increases the height of the seedling and gives more leaves.	Soaking seeds in cow urine for 12 hours resulted in 66.11% germination, and soaking them in cow dung solution for 12 hours increased the plant height by 33.19 cm and the number of leaves.	Shinde and Malshe (2015) ^[44]

Table 3: Comparative Evaluation of Pre-Sowing Seed Treatment in *Acacia catechu*

S. N	Species	Method of Seed treatment	Effect	Germination	Author and year
1.	<i>Acacia catechu</i> and <i>Elaeocarpus floribundu</i>	Hot water treatment for 10 mint 80 °C and H ₂ SO ₄ 12 mint 80% and scarification	Softens the seed code and breaks physical dormancy, increase water absorption and faster germination	<i>A. catechu</i> (91.26%) hot water treatment <i>E. floribundu</i> (86.35%) H ₂ SO ₄ in 12 mint	Das <i>et al.</i> (2014) ^[45]
2.	<i>Acacia modesta</i>	Mechanical, chemical, and organic methods,	Helps break the hard seed code, accelerates germination, increases seedling growth and enhances nutrient uptake	Mechanical, scarification resulted in the highest germination (65.83%)	Saurav <i>et al.</i> , (2022) ^[46]
3.	<i>A. etbaica</i> , <i>A. hamouloosa</i> , and <i>A. tortilis</i> , <i>A. origena</i> <i>A. asak</i> , <i>A. ehrenbergiana</i> , and <i>A. johnwoodii</i>	Sulfuric acid treatment 10-14 mint and hot water treatment 1 mint	Helps seeds absorb water rapidly, and early germination, and grows uniformly, Improves seedling vigour	The highest germination% in sulfuric acid <i>A. asak</i> 100% followed by <i>A. hamouloosa</i> 96% <i>A. ethacica</i> 95% and <i>A. tortillis</i> 89% and <i>A. origena</i> hot water 83%	Alzandi <i>et al.</i> (2025) ^[47]
4.	<i>Acacia catechu</i> Willd	Cold water treatment in 24 hours and control	This is a simple and low-cost method that initiates the metabolic activity necessary for germination.	The highest germination was in the cold-water treatment at 80-81% for 24 hours and the lowest was in the control 62%	Haider <i>et al.</i> , (2014) ^[48]
5.	<i>A. nilotica</i> , whereas in <i>A. seyal</i> , <i>A. senegal</i> , and <i>A. mellifera</i> ,	Hot water treatment and Sulfuric acid treatment (H ₂ SO ₄)	Promotes seedling growth, improves early growth and uniformity in seedlings increases germination percentage and helps in softening the hard seed code	The highest germination% sulphuric acid was observed in 10-90 minutes for <i>A. nilotica</i> 81%, <i>A. seyal</i> 74%, <i>A. mellifera</i> 15% and <i>A. senegal</i> 5% and Hot water treatment 20 mint 30.5 and 39.5% <i>A. senegal</i> and <i>A. mellifera</i>	Yousif <i>et al.</i> (2019) ^[14]

7. Growth parameter

Growth parameters are indicators used to assess plant growth, development, and quality, helping to determine plant height and the length of roots and leaves of trees and

plants. These indicators allow us to easily monitor plant growth and development, and determine which treatments are best for plant growth, including which treatments increase the number of leaves, height, and collar diameter.

Therefore, the study of growth parameters is essential for assessing the effectiveness of different seed treatments and nursery techniques, as they are considered indicators of

plant growth and quality. (SC Grossnickle, JE MacDonald 2018)^[49]

Table 3: Comparative Analysis of Growth Parameter under Various Pre-Sowing Treatment

S. N	Treatment	Species	Germination%	Plant Height	Number of leaves	Root length	Shoot length	Author and year
1.	Scarification concentrate H ₂ SO ₄ 10 mint	<i>Acacia mangium</i>	90.67%	-----	10.00	4.58 cm	7.20 cm	Patil <i>et al.</i> , (2012) ^[32]
2.	Hot water, sulphuric acid, cold water treatment	<i>Acacia nilotica</i>	76.2% (H ₂ SO ₄ 3 mint)	9.99 cm	-----	8.09 cm	-----	Gilani <i>et al.</i> , (2019) ^[50]
3.	Hot water, sulphuric acid, cold water treatment	<i>Acacia Senegal</i>	90.5% (H ₂ SO ₄ 3 mint)	-----	-----	-----	-----	Olujobi <i>et al.</i> , (2024) ^[51]
4.	Lukewarm water, Cold water treatment	<i>Acacia senegal</i>	70% (lukewarm treatment 12 h)	34.3 cm 4 weeks	-----	4.5 cm 4 weeks	-----	Grace <i>et al.</i> , (2020) ^[51]

Discussion

Comparative analyses show that pre-sowing treatments significantly improve seed germination in *Acacia* varieties by eliminating seed coat dormancy and increasing water absorption capacity. Sulfuric acid scarification resulted in higher germination rates, with 90.67% for *Acacia mangium* and 90.5% for *A. senegal* (Patil *et al.*, 2012; Olujobi *et al.*, 2024). Hot water treatment was also effective, especially for *Acacia catechu*, where 91.26% germination was recorded (Das *et al.*, 2014). Cold water treatment resulted in 80-81% germination rates for *A. catechu*, compared to 62% for the control (Haider *et al.*, 2014). Mechanical scarification resulted in higher germination rates for Germination was also improved in *A. modesta*, reaching 65.83% (Saurav *et al.*, 2022). Overall, the results indicate that sulfuric acid, hot water, and cold-water treatments are effective methods for inducing physiological dormancy, although the best treatment varies between *Acacia* species.

Conclusion

Acacia catechu is an economical and medicinal tree but due to hard seed coat in its seed dormancy is found due to which germination and inequality have been observed. It has been seen from comparative study of various research studies that pre-sowing treatment methods are adopted which play an important role in breaking the seed dormancy and increasing the growth of plants like hot water treatment, sulfuric acid treatment, cold water treatment, and mechanical scarification, therefore that germination is fast. The most suitable treatment for acacia species has been found to be soaking in hot water in which germination up to 91.26% was observed and at the similar time sulfuric acid treatment has been found to be up to 81%. These treatments improved germination speed and increased plant growth and vigour. Therefore, these treatments may prove useful for large-scale plant production and conservation. Further detailed research is needed to evaluate the long-term effects and develop successful and effective strategies for sustainable production and conservation of this species.

Acknowledgment

The authors are deeply grateful for the support of the institutions that helped prepare this review article and for the availability of academic and scientific literature. The authors are also grateful to all the researchers whose published work provided valuable information and scientific insights for this review. No specific financial support was received in the preparation of this manuscript.

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