International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(9): 306-309
www.biochemjournal.com
Received: 25-07-2025
Accepted: 30-08-2025

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Breaking dormancy and boosting vigor: Comparative effects of seed treatments on germination and seedling growth in *Melia dubia*

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i9Sd.5510

Abstract
The study investigated the effect of different seed treatments and potting media on the germination and early seedling growth of *Meliadubia* Cav., a fast-growing industrial tree species with poor natural germination. The experiment was conducted during 2021-22 at UAS, GKVK, Bengaluru, using a Completely Randomized Design (CRD) comprising nine treatments with four replications. Results indicated that scarification with 1% H_2SO_4 significantly improved germination percentage (63.88%), speed (0.97), and capacity (75.50%). Soaking in cow dung slurry also enhanced germination (54.05%) and shoot growth. Hormonal treatments (GA_3, Cytokinin, NAA) influenced seedling vigour parameters but were less effective for germination enhancement. The findings suggest that simple organic and chemical treatments can significantly improve seedling production for forestry and agroforestry systems.

Keywords: *Meliadubia*, seed germination, seed treatments, cow dung slurry, acid scarification, seedling growth

Introduction

Forests play an essential role in maintaining ecological balance and supporting livelihoods around the world. As the demand for timber, pulp, and biomass continues to grow in India, fast-growing and multipurpose tree species have become indispensable to meet both commercial and environmental needs. Among these, *Meliadubia* Cav., commonly known as Malabar neem, stands out due to its exceptional growth rate, adaptability to diverse agroclimatic conditions, and utility in a wide range of industries, including plywood, furniture, and bioenergy (Krishna *et al*., 2011; Kumar *et al*., 2021) [5, 6].

Despite its commercial potential and increasing popularity in agroforestry systems, one of the persistent challenges faced by nursery managers and growers is the poor natural germination of *Meliadubia* seeds. This limitation arises from its hard and impermeable seed coat, which restricts water absorption and gaseous exchange, ultimately delaying or preventing germination (Thanuja *et al*., 2019) [8]. Without proper intervention, this low germination rate can lead to inconsistent seedling production and inefficiencies in afforestation and farm forestry programs.

To address this, a variety of pre-sowing seed treatments have been explored to improve germination performance. Techniques such as acid scarification, soaking in water, and chemical priming are commonly employed to soften the seed coat and stimulate physiological processes within the seed (Gupta and Bhardwaj, 2005) [3]. In addition, the use of plant growth regulators like gibberellic acid (GA_3), cytokinin, and auxins (such as NAA) has shown promise in promoting seedling emergence and early growth (Anand *et al*., 2012) [1]. Traditional organic methods, like cow dung slurry soaking, continue to offer a sustainable, low-cost alternative for enhancing germination by leveraging natural microbial activity and hormonal compounds (Thanuja *et al*., 2019) [8].

Moreover, the success of seedling establishment depends not only on seed treatment but also on the quality of the nursery environment, especially the composition of potting media. Soil texture, nutrient content, water-holding capacity, and microbial activity all influence seedling vigour, root development, and biomass accumulation.

Thus, integrating effective seed treatments with suitable nursery management practices is key to maximizing the propagation potential of *Meliadubia*.

Given the limited literature on comprehensive studies evaluating both seed treatments and nursery performance in *Meliadubia*, this research was undertaken to fill the gap. The objective was to assess the impact of various chemical, hormonal, and organic seed treatments on germination percentage, germination speed, and early seedling growth under controlled nursery conditions. The findings aim to offer practical recommendations for nursery managers, farmers, and agroforestry practitioners to improve the propagation efficiency of this valuable tree species. to evaluate the effect of different seed treatments, including chemical, hormonal, and organic methods, on the germination and early seedling vigour of *Meliadubia*. The findings aim to provide practical, low-cost solutions to enhance nursery efficiency and promote the wider adoption of this important agroforestry species. to evaluate the effect of different seed treatments, including chemical, hormonal, and organic methods, on the germination and early seedling vigour of *Meliadubia*. The findings aim to provide practical, low-cost solutions to enhance nursery efficiency and promote the wider adoption of this important agroforestry species. The impact of various seed treatments and potting media on the germination behaviour and early growth performance of *Meliadubia*, to identify cost-effective propagation methods.

2. Materials and Methods

2.1 ExperimentalSite

The research was carried out at the College of Forestry, University of Agricultural Sciences, GKVK, Bengaluru, during the academic year 2021-22. Nestled at an elevation of 924 meters above sea level, the site experiences a tropical savanna climate with pleasant temperatures ranging from 24-28 °C and moderate annual rainfall. The soil in the experimental area is classified as red sandy loam—light, well-draining, and slightly acidic (pH 6.08)—with moderate levels of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). Prior to initiating the experiment, the soil was analyzed to understand its fertility profile and ensure uniform conditions across all experimental units (Anand *et al*., 2012) [1].

2.2 Experimental Design and Treatments

Table 1: Description of seed treatment methods applied to *Meliadubia* seeds

Treatment Code	Description of Seed Treatment
T_9	Control (untreated seeds)
T_2	Soaking in 1% Hydrogen peroxide (H_2O_2) for 20 minutes
T_3	Scarification with 1% Sulphuric acid (H_2SO_4) for 20 minutes
T_4	Soaking in 1% Potassium nitrate (KNO_3) for 20 minutes
T_5	Soaking in Gibberellic acid (GA_3) @ 500 ppm for 6 hours
T_6	Soaking in Cytokinin @ 100 ppm for 6 hours
T_7	Soaking in Naphthaleneacetic acid (NAA) @ 100 ppm for 6 hours
T_8	Soaking in cow dung slurry for 10 days with three drying cycles
T_9	Soaking in distilled water for 6 hours

After applying the treatments, the seeds were sown in germination trays filled with sterilized sand to observe initial germination. Once germinated, the seedlings were transferred into polybags containing a standard nursery mixture (red soil, sand, and farmyard manure in a 2:1:1 ratio). All seedlings were maintained under partial shade, irrigated regularly, and protected from pest and disease infestations to ensure uniform growth conditions (Thanuja *et al*., 2019) [8].

2.3 Observations Recorded

A series of qualitative and quantitative observations were taken at various stages of germination and early seedling development. These included:

- Germination percentage
- Abnormal seedlings, hard seeds, and dead seeds
- Days to initial germination
- Germination speed (Heydecker's formula)
- Germination capacity
- Shoot and root length
- Root: shoot ratio
- Collar diameter
- Seedling biomass and sturdiness quotient

2.4 Statistical Analysis

The recorded data were subjected to statistical analysis using Analysis of Variance (ANOVA) under the Completely Randomized Design framework. To determine whether treatment differences were statistically significant, the Least Significant Difference (LSD) test was applied at a 5% significance level. All calculations and inferences were drawn using standard software packages such as OPSTAT and SPSS.

3. Results and Discussion

In this section, we delve into the outcomes observed during the study and their broader significance. The findings highlight how simple, accessible interventions can substantially improve the germination and early development of *Meliadubia*, a species often hampered by dormancy issues. Each parameter was carefully monitored and analyzed to understand not only which treatments worked, but why they did so—and how they might be applied effectively in real-world nursery settings.

3.1 Germination Parameters

The results showed a significant impact of seed treatments on germination percentage, speed, and seedling emergence behavior. Among all treatments, scarification with 1% H_2SO_4 (T_3) resulted in the highest germination percentage (63.88%), followed by the traditional cow dung slurry treatment (T_8) which recorded 54.05%. The control (T_9) performed the poorest with only 26.80% germination. This clearly demonstrates that dormancy in *Meliadubia* is largely physical and can be overcome by mechanical or biochemical means that facilitate water absorption.

The percentage of hard seeds was also drastically reduced in acid-scarified seeds (21.02%), compared to untreated seeds (57.60%), confirming the efficacy of H_2SO_4 in weakening the seed coat. Abnormal seedlings were more frequent in the hormonal treatments (e.g., GA_3, NAA), indicating that while hormones may stimulate metabolic activity, they are not effective without prior dormancy release. The number of dead seeds was relatively consistent across treatments, implying that seed viability was not a major limiting factor.

In addition to germination percentage, the timing and uniformity of germination were assessed using days to initial germination, germination speed, and germination capacity. Scarification with 1% H_2SO_4 (T_3) not only produced the highest germination percentage but also had the fastest germination onset (24.25 days) and the highest germination speed (0.97), indicating a rapid and synchronized seedling emergence. The cow dung slurry treatment (T_8) also recorded early germination (26.25 days) with a germination speed of 0.94 and a capacity of 75.50%, making it a strong organic alternative.

In contrast, untreated seeds (T_9) took 35.00 days to initiate germination, with a low germination speed of 0.70 and a capacity of only 33.25%, confirming the slow and inconsistent emergence typically seen in untreated hard-coated seeds. Hormonal treatments such as GA_3 and NAA showed moderate improvements in germination capacity and speed but were less effective than H_2SO_4 and cow dung slurry in reducing the time to initial germination.

These results underscore the effectiveness of acid scarification and cow dung slurry in not only breaking dormancy but also ensuring a faster and more uniform germination process—an essential trait for achieving uniform seedling lots in nurseries (Table 2 & 2a).

3.2 Seedling Vigor and Growth

Treatments significantly affected seedling shoot and root growth. The cow dung slurry (T_8) recorded the longest shoot length (15.52 cm), followed by cytokinin (T_6) and GA_3 (T_5), indicating their role in cell elongation and shoot expansion. However, root length was maximized in NAA treatment (T_7) with 7.64 cm, showing auxin's influence on root development. Acid-treated seeds also maintained a good balance in shoot and root proportions, favoring transplant stability (Table 3).

3.3 Comparative Analysis and Implications

To make sense of the wide range of responses observed in germination and seedling traits, we integrated both the germination percentage and seedling vigour data into a single index—Seedling Vigour Index (SVI). This provided a more holistic measure of each treatment's performance. (Table 4)

Not surprisingly, the acid scarification treatment (T_3) emerged as the front-runner. It achieved the highest germination rate and performed strongly in shoot and root development, leading to an SVI of 1187.49. In practical terms, this means not just more seeds sprouting, but more uniform, robust seedlings—an outcome highly desirable in any nursery setting.

Close on its heels was the cow dung slurry treatment (T_8), a traditional yet powerful technique. It delivered slightly lower germination than T_3, but its long shoot and root lengths pushed the SVI up to 1157.67. For nurseries aiming to adopt low-cost and organic-friendly methods, this makes T_8 an especially attractive option.

Other treatments like GA_3 (T_5), Cytokinin (T_6), and NAA (T_7) showed moderate success, suggesting their potential role in boosting early seedling vigour when used with dormancy-breaking techniques. Interestingly, even though water soaking (T_9) and hydrogen peroxide (T_2) treatments led to some improvement over the control, their gains were modest.

Ultimately, the control treatment (T_9) lagged behind with the lowest SVI, reaffirming the challenge posed by untreated *Meliadubia* seeds, which exhibit poor and erratic germination.

These results support the idea that integrating simple chemical or organic pre-sowing interventions can go a long way in improving nursery success. While acid scarification proved most effective, its practical limitations (safety, handling) highlight the importance of alternatives like cow dung slurry—accessible, eco-friendly, and effective.

Table 2: Germination and Seed Quality Components of *Meliadubia* Under Different Seed Treatments

Treatment Code	Germination (%)	Normal Seedlings (%)	Abnormal Seedlings (%)	Hard Seeds (%)	Dead Seeds (%)
T_9-Control	26.80	20.63	6.18	57.60	15.60
T_2-H_2O_2 1% (20 min)	30.88	25.00	6.00	54.20	14.80
T_3-H_2SO_4 1% (20 min)	63.88	43.15	20.70	21.02	15.10
T_4-KNO_3 1% (20 min)	28.78	20.13	8.65	55.72	15.50
T_5-GA_3 500 ppm (6 h)	34.20	21.95	12.38	50.77	14.90
T_6-Cytokinin 100 ppm (6 h)	32.48	12.48	20.20	52.82	14.50
T_7-NAA 100 ppm (6 h)	31.55	20.28	11.28	53.15	15.30
T_8-Cow dung slurry	54.05	37.40	16.65	30.95	15.00
T_9-Water soaking (6 h)	35.43	20.00	15.43	49.02	15.55

Table 2a: Days to Initial Germination, Germination Speed, and Germination Capacity Under Different Treatments

Treatment Code	Days to Initial Germination	Germination Speed	Germination Capacity (%)
T_9-Control	35.00	0.70	33.25
T_2-H_2O_2 1% (20 min)	32.50	0.77	37.50
T_3-H_2SO_4 1% (20 min)	24.25	0.97	75.50
T_4-KNO_3 1% (20 min)	33.25	0.75	35.60
T_5-GA_3 500 ppm (6 h)	29.25	0.85	49.85
T_6-Cytokinin 100 ppm (6 h)	30.50	0.78	42.20
T_7-NAA 100 ppm (6 h)	28.75	0.80	41.80
T_8-Cow dung slurry	26.25	0.94	75.50
T_9-Water soaking (6 h)	31.75	0.76	46.20

Table 3: Seedling Growth Characteristics of *Meliadubia* Under Different Seed Treatments

Treatment Code	Shoot Length (cm)	Root Length (cm)	Root:Shoot Ratio
T_9-Control	8.22	2.99	0.36
T_2-H_2O_2 1% (20 min)	9.67	3.54	0.37
T_3-H_2SO_4 1% (20 min)	14.37	4.22	0.29
T_4-KNO_3 1% (20 min)	12.11	4.82	0.40
T_5-GA_3 500 ppm (6 h)	13.52	6.33	0.47
T_6-Cytokinin 100 ppm (6 h)	15.33	3.31	0.22
T_7-NAA 100 ppm (6 h)	11.21	7.64	0.68
T_8-Cow dung slurry	15.52	5.88	0.38
T_9-Water soaking (6 h)	9.77	3.66	0.37

Table 4: Combined Ranking of Treatments Based on Germination Percentage and Seedling Vigor Index (SVI)

Rank	Treatment	Germination (%)	Shoot + Root Length (cm)	SVI	Remarks
1	T_3-H_2SO_4	63.88	18.59	1187.49	Fast, uniform, vigorous growth
2	T_8-Cow dung slurry	54.05	21.40	1157.67	Organic, effective, and safe
3	T_5-GA_3	34.20	19.85	678.57	Promotes shoot elongation
4	T_6-Cytokinin	32.48	18.64	605.10	Best for shoot growth
5	T_7-NAA	31.55	18.85	594.34	Best for root development
6	T_9-Water soaking	35.43	13.43	475.97	Simple and accessible
7	T_2-H_2O_2	30.88	13.21	407.99	Moderate improvement
8	T_4-KNO_3	28.78	16.93	487.67	Weak improvement
9	T_9-Control	26.80	11.21	300.43	Poor vigor, low germination

4. Conclusion

This study provides conclusive evidence that seed germination and early seedling development in *Meliadubia* can be significantly improved through strategic pre-sowing treatments. Among the various approaches tested, scarification with 1% H_2SO_4 demonstrated the highest efficacy in breaking physical dormancy, promoting rapid and uniform germination, and improving overall seedling vigor. Cow dung slurry emerged as a competitive and sustainable alternative, combining effective germination stimulation with improved seedling growth parameters. Hormonal treatments, while moderately effective, were less consistent in performance and are better suited as supplementary interventions. Based on integrated germination metrics and the Seedling Vigour Index, the study recommends the adoption of either acid scarification or cow dung slurry soaking—depending on nursery capacity and safety considerations—for scalable propagation of *Meliadubia*. These findings hold significant relevance for agroforestry systems, commercial forestry operations, and afforestation initiatives aiming for cost-effective and high-quality seedling production. Among the evaluated methods, scarification with 1% H_2SO_4 and soaking in cow dung slurry were found to be the most effective in improving germination rate, speed, and seedling vigour. These low-cost, practical techniques are recommended for adoption in nurseries and afforestation programs aiming to promote this valuable agroforestry species.

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