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Effects of different pre-sowing seed treatments on germination and seedling growth of *Terminalia Catappa* L

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Abstract

The tropical almond tree, *Terminalia catappa* L., is valued for its edible kernels, shade, and therapeutic properties, but large-scale nursery production is constrained by its dense, woody, fibrous endocarp, which causes slow and uneven physical seed dormancy. To address this constraint, six pre-sowing treatments were evaluated on 270 seeds sown between April and June 2026, using a Completely Randomized Design (CRD) with three replications. The treatments comprised T₀ (control), T₁ (GA₃ at 200 ppm for 24 hours), T₂ (H₂SO₄ at 1% for 5-10 minutes), T₃ (hot water at 70°C for 5 minutes), T₄ (cold-water soaking for 24 hours), and T₅ (cold-water soaking for 48 hours). Treatment T₄ produced the best overall response, significantly enhancing physiological activation and yielding the highest germination percentage (88.88%), mean daily germination (0.98%), germination value (4.65), and peak value (4.71). At 90 days after sowing, T₄ also produced superior seedling growth, including the greatest plant height (26.41 cm), number of leaves per seedling (15.13), shoot diameter (0.43 cm), and root length (33.76 cm). In contrast, the untreated control exhibited the lowest germination percentage (35.55%), the longest time to emergence (60.06 days), and stunted seedling growth. These findings indicate that a 24-hour cold-water soak (T₄) is an effective, low-cost pre-sowing treatment that can be recommended as the standard practice for large-scale nursery production of *T. catappa*.

Keywords: Therapeutic properties, physical dormancy, nursery production, nursery management

Introduction

Terminalia catappa, a large deciduous tropical tree of the family Combretaceae, is commonly known as the tropical almond or Indian almond. Native to the coastal regions of Asia, Africa, and Australia, this highly adaptable species is widely cultivated throughout the tropics for its edible kernels, shade, and ornamental value (Phulwaria *et al.*, 2012) ^[18]. The tree typically attains a height of 15-25 m. Global annual production of fruit and seed has been estimated at 700,000 tons, with each tree yielding approximately 5 kg of kernels per year (Ezeokonkwo and Dodson, 2004). *T. catappa* has a straight bole and tiers of horizontal, whorled branches arranged in a distinctive, symmetrical pagoda-like growth habit. Large, glossy, obovate leaves are clustered at the branch tips; before being shed twice a year, the accumulation of pigments such as violaxanthin and lutein produces a conspicuous seasonal change in leaf colour, from red to copper to gold. The species is monoecious, bearing small, inconspicuous greenish-white flowers on axillary spikes, with bisexual flowers at the base of the spike and male flowers toward the tip. The fruit is a flattened, ellipsoidal drupe that changes colour from green to yellow to reddish-purple as it matures. Its fibrous, spongy pericarp confers buoyancy and facilitates seed dispersal by ocean currents (hydrochory), while a single almond-flavoured kernel is enclosed within the hard, fibrous endocarp. Owing to its exceptional tolerance of salinity and drought, *T. catappa* serves as an important windbreak and soil stabiliser in coastal environments (Ramanan *et al.*, 2025) ^[20]. Its senescent leaves are rich in tannins and flavonoids, including punicalagin and catappanin, and are widely used in aquaculture to condition water and reduce pH owing to their antifungal and antibacterial properties (Hossain *et al.*, 2013) ^[12]. Extracts from the leaves, bark, and fruit exhibit potent antioxidant, hepatoprotective, and anti-inflammatory activity, underscoring the species'

importance in ethnomedicine and biochemistry. Wider cultivation of *T. catappa* has also been proposed as a means of increasing urban greenery in areas where the species remains uncommon (Ramanan *et al.*, 2026) [21].

Hard-seed-coat dormancy, caused by the stony endocarp of *Maesopsis eminii* and *Terminalia catappa*, restricts water penetration and, in the absence of pre-germination treatment, results in erratic or delayed germination (Azad *et al.*, 2013) [4]. This form of dormancy is classified as physical dormancy, in which a water-impermeable palisade layer in the seed or fruit coat prevents inhibition until the layer is disrupted (Baskin and Baskin, 2004) [6]. Several approaches have been developed to enhance the germination of hard-coated seeds prone to this form of dormancy (Morpeth and Hall, 2000). Because an intact seed coat restricts water uptake and gaseous exchange, seed-coat scarification is essential for overcoming physical dormancy; the fissures created during mechanical or chemical treatment permit water entry and gas exchange, thereby enabling enzymatic hydrolysis and subsequent development of the embryo into a seedling (Shil and Prajapati, 2026) [23]. Gibberellic acid treatment offers a complementary hormonal route to overcoming dormancy, having been shown to enhance germination value in other hard-seeded species such as oak (Adams *et al.*, 2010) [2]. Pre-sowing treatments are therefore essential for improving germination in species with inherently poor germination, whether arising from hard seed coats or other forms of dormancy. According to Markam *et al.* (2025) [14], the objective of nursery operations for any given species is to produce the maximum number of high-

quality seedlings with the minimum expenditure of labour, cost, and time. The present study evaluated soaking treatments for improving the germination of a hard-coated indigenous tree species, with the aim of guiding institutions and individuals engaged in tree nursery operations. Seed treatments offer considerable scope for breaking seed dormancy, improving germination rate and uniformity, and reducing the time to emergence (Bargah *et al.*, 2025; Maan and Jain, 2026) [5, 13]. Judicious use of industrial by-products such as fly ash also offers promising prospects for improving soil fertility and nursery sustainability (Behera *et al.*, 2020) [7]. Despite persistent challenges such as seed dormancy and environmental stress, advances in seed technology and adaptive nursery management continue to offer opportunities for improving propagation performance (Netam *et al.*, 2025) [15].

Materials and Methods

The experiment was conducted from April to June 2026 (cropping year 2025-26) at Khudmudi Phase-2, College of Forestry and Research Station, Sankara-Patan, Durg, Chhattisgarh (21.120°N, 81.570°E; altitude 215.10 m above mean sea level). The site experiences a tropical climate characterized by a distinct monsoon season, hot summers, and mild winters. Summers (April-June) are hot and dry, with maximum temperatures of 45-48°C, while the monsoon, extending from late June to September, contributes most of the annual rainfall that sustains the region's forestry and agricultural sectors.



Fig 1: Geographical location of Durg District, Chhattisgarh.

Seed collection area

Trees of *Terminalia catappa* were sampled locally from Barnavapara, and seed lots were collected from the selected trees. From the collected seed, 270 seeds were separated and randomly

allocated among six treatments, including the control.

Pre-sowing treatments

Seeds of *Terminalia catappa* were subjected to six pre-sowing

treatments to evaluate their effect on germination behaviour, following standard tree-seed pre-treatment procedures (Food and Agriculture Organization of the United Nations, 1993); details of the treatments are presented in Table 1.

Table 1: Different methods of pre-sowing treatments

Notation	Treatments
T ₀	Control
T ₁	GA ₃ 200ppm for 24 hours
T ₂	H ₂ SO ₄ at 1% 5-10 minutes
T ₃	Hot water at 70°C for 5 minutes
T ₄	Soaking in cold water for 24 hours
T ₅	Soaking in cold water for 48 hours

Experimental design

The germination trial was laid out in a Completely Randomized Design (CRD), with three replications per treatment (six treatments including the control). For each replication, 15 seeds were sown individually in polybags (one seed per bag) containing a potting medium of soil, sand, farmyard manure (FYM), and cocopeat in a 5:1:1:1 ratio, giving 45 seeds per treatment. Germination was recorded daily; a seedling was considered to have emerged once it appeared above the soil surface, and both the number of days to emergence and the number of seedlings emerged were recorded. Data were subjected to analysis of variance and treatment means were compared following standard procedures for agricultural experimentation (Panse and Sukhatme, 1967) [17].

Germination percentage

Germination in each treatment was recorded daily for up to 90 days. Seeds were considered germinated when the cotyledonary leaves emerged above the soil surface, and the percentage seed germination was calculated from the daily germination counts.

Germination percentage = (Number of seeds germinated × 100) / (Number of seeds sown)

Mean daily germination (%) = (Cumulative percent germination) / (Total number of days)

Peak value (PV) = maximum mean daily germination reached at any stage of the germination period.

Germination value = Mean daily germination × peak value

Results and discussion

The goal of the present study was to see how different pre-sowing treatments affected seed germination of *Terminalia catappa*.

Number of days to plant emergence

All pre-sowing treatments reduced the number of days to seedling emergence relative to the untreated control (Table 2, Fig. 2). Seedlings emerged earliest under T₃ (hot water at 70°C for 5 minutes; 18.86 DAS), followed by T₄ (cold-water soak for 24 hours; 21 DAS) and T₅ (cold-water soak for 48 hours; 22.86 DAS). Emergence in T₂ (1% H₂SO₄ for 5-10 minutes) required 40.93 DAS. Emergence under T₁ (GA₃ at 200 ppm for 24 hours) required 33.80 DAS, while the untreated control (T₀) required 60.06 DAS. Odoi *et al.*, (2019) [16] similarly reported that a 12-hour cold-water soak markedly accelerated seedling emergence in *Terminalia catappa* relative to an untreated control, while Sharma *et al.*, (2008) [22] reported that hot-water treatment reduced the time to seedling emergence in several fast-growing tropical tree species with hard seed coats, consistent with the rapid emergence

recorded under T₃ in the present study.

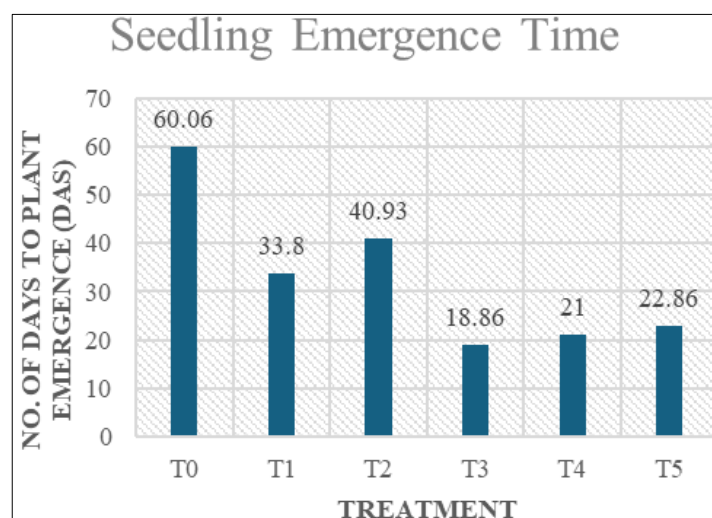


Fig 2: Number of days to plant emergence of *Terminalia catappa*.

Germination percentage

Germination percentage was highest in T₄ (88.88%; cold-water soak for 24 hours), followed by T₃ (77.77%; hot water at 70°C for 5 minutes) and T₅ (66.66%; cold-water soak for 48 hours) (Table 2, Fig. 3). The hormonal and chemical treatments, GA₃ at 200 ppm for 24 hours (T₁) and H₂SO₄ at 1% for 5-10 minutes (T₂), produced germination percentages of 53.33% and 46.66%, respectively — higher than the untreated control (35.55%) but lower than the water-based treatments (T₃, T₄, T₅). Purohit *et al.*, (2015) [19] similarly reported that dilute sulfuric acid scarification markedly improved germination in the hard-coated seeds of *Zanthoxylum armatum*, underscoring the effectiveness of acid scarification for breaking physical dormancy in woody species, although its relative efficacy in the present study remained lower than that of water-based physical treatments.

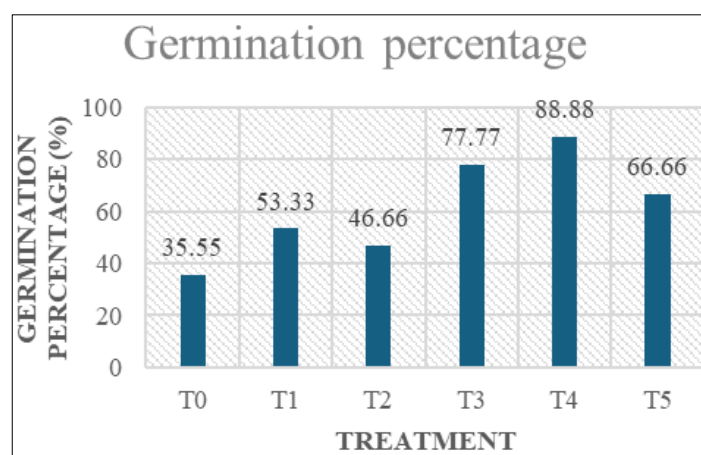


Fig 3: Germination percentage (%) of *Terminalia catappa*.

Mean daily germination, peak value, germination value

Mean daily germination was highest in T₄ (0.98%), followed by T₃ (0.86%), T₅ (0.74%), T₁ (0.59%), and T₂ (0.51%); the control recorded the lowest value (0.39%). A similar trend was observed for peak value, which was highest in T₄ (4.71) and lowest in the control (0.59), and for germination value, which was highest in T₄ (4.65), followed by T₃ (3.20), and lowest in the control (0.23).

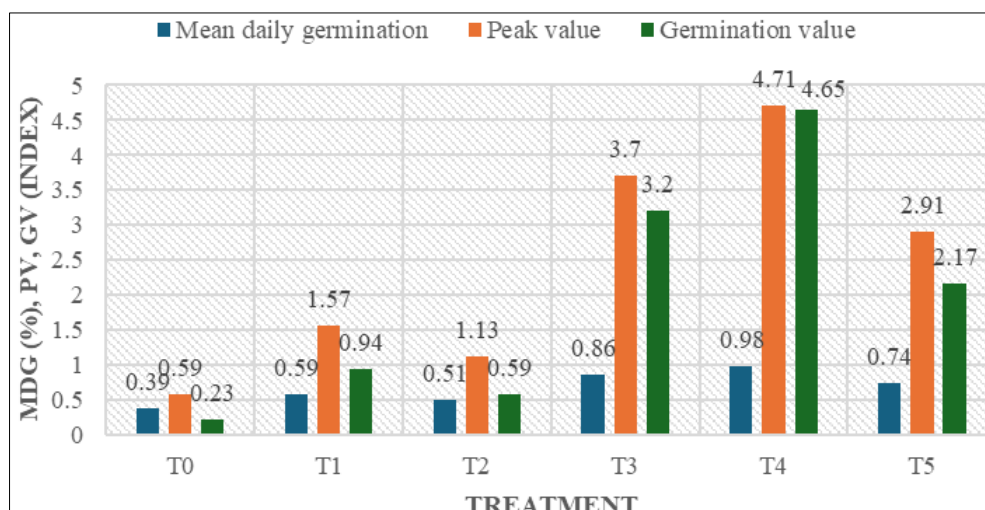


Fig 4: Effect of different pre-sowing treatments on mean daily germination, peak value, and germination value of *Terminalia catappa*

Plant height (CM)

Plant height of *T. catappa* seedlings differed significantly ($P < 0.05$) among pre-sowing treatments at 30, 60, and 90 DAS (Table 3, Fig. 5), and increased progressively with seedling age under every treatment. At 30 DAS, plant height was greatest in T₄ (10.91 cm), followed by T₃ (8.42 cm) and T₅ (7.54 cm); seedlings of T₀,

T₁, and T₂ had not yet emerged at this stage. At 60 DAS, T₄ again recorded the greatest plant height (16.41 cm), followed by T₃ (13.92 cm) and T₅ (13.04 cm), while the control (T₀) recorded the lowest height (3.62 cm). At 90 DAS, T₄ produced the tallest seedlings (26.41 cm), followed by T₃ (22.92 cm) and T₅ (21.04 cm), whereas the control remained shortest (13.62 cm).

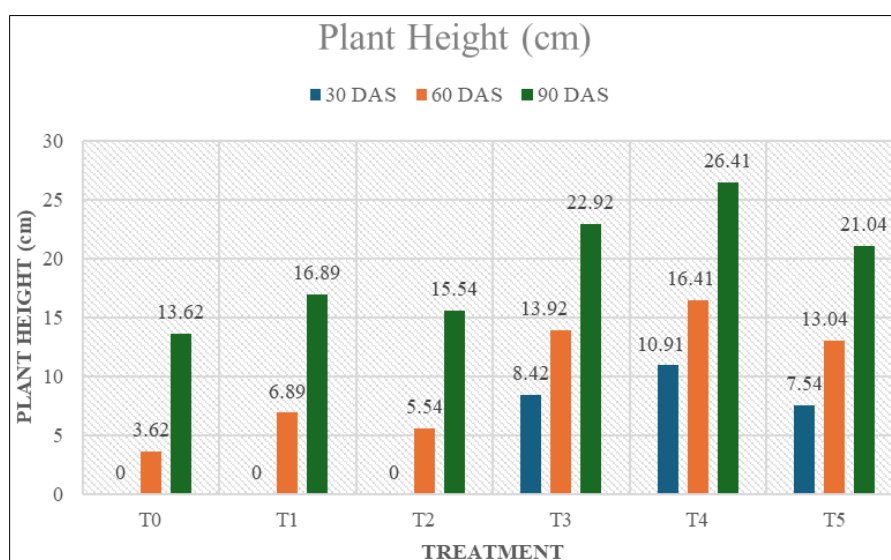


Fig 5: Plant height at 30, 60, and 90 days of *Terminalia catappa*.

Number of leaves per plant

The number of leaves per seedling differed significantly ($P < 0.05$) among pre-sowing treatments at 30, 60, and 90 DAS (Table 3, Fig. 6), and increased markedly with seedling age under every treatment. At 30 DAS, the highest leaf number was recorded in T₄ (3.86), followed by T₃ (3.66) and T₅ (1.20); seedlings of T₀, T₁,

and T₂ had not yet emerged at this stage. At 60 DAS, T₄ again produced the greatest number of leaves per seedling (10.20), followed by T₃ (8.80) and T₅ (4.93), while the control recorded the fewest (0.86). At 90 DAS, T₄ produced the highest leaf number (15.13), followed by T₃ (13.80) and T₅ (9.93), while the control recorded the lowest value (6.26).

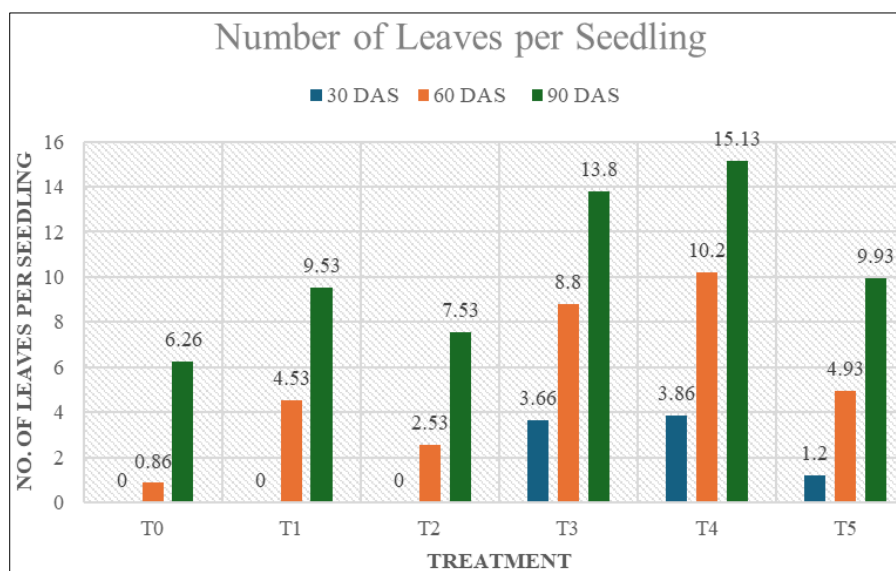


Fig 6: Number of leaves per plant at 30, 60, and 90 days of *Terminalia catappa*.

Shoot diameter

Shoot diameter differed significantly ($P < 0.05$) among pre-sowing treatments at 30, 60, and 90 DAS (Table 3, Fig. 7), increasing progressively with seedling age under all treatments. At 30 DAS, the largest shoot diameter was recorded in T₄ (0.13 cm), followed by T₃ (0.12 cm) and T₅ (0.09 cm); seedlings of T₀,

T₁, and T₂ had not yet emerged at this stage. At 60 DAS, T₄ again recorded the largest shoot diameter (0.23 cm), followed by T₃ (0.22 cm) and T₅ (0.21 cm), while the control recorded the smallest diameter (0.08 cm). At 90 DAS, T₄ produced the largest shoot diameter (0.43 cm), followed by T₃ (0.42 cm) and T₅ (0.41 cm), while the control remained smallest (0.23 cm).

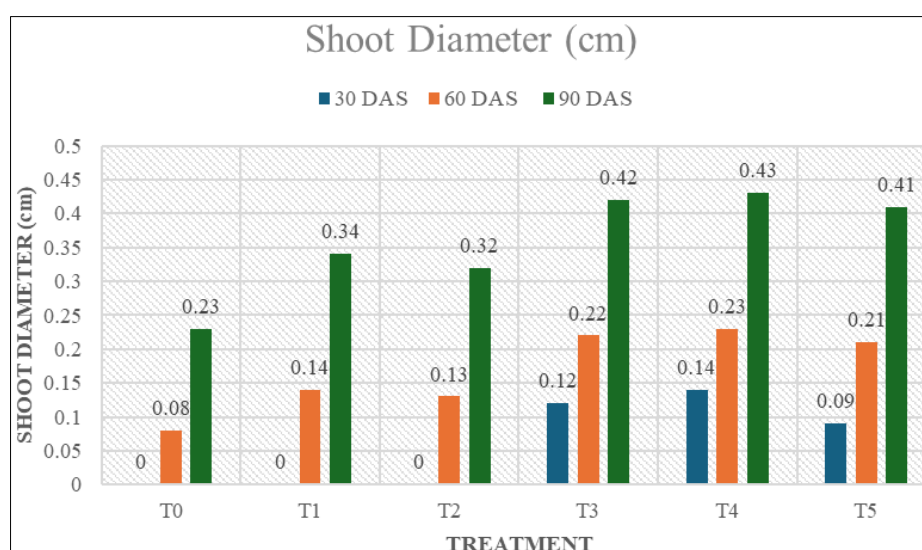


Fig 7: Effect of different pre-sowing treatments on shoot diameter (cm) of *Terminalia catappa*

Root length

Root length differed significantly ($P < 0.05$) among pre-sowing treatments at 90 DAS (Table 3, Fig. 8). Treatment T₄ (cold-water soak for 24 hours) produced the longest roots (33.76 cm), followed by T₃ (hot water at 70°C for 5 minutes; 33.61 cm) and T₅ (cold-water soak for 48 hours; 27.68 cm), while the control recorded the shortest root length (16.81 cm).

Root diameter

Root diameter of *T. catappa* seedlings also differed significantly

($P < 0.05$) among pre-sowing treatments at 90 DAS (Table 3, Fig. 8). The largest root diameter was recorded in T₄ (0.47 cm), followed by T₃ (0.46 cm) and T₅ (0.44 cm), while the control produced the smallest root diameter (0.25 cm). Overall, the water-based physical treatments outperformed the chemical treatments across all measured seedling growth parameters, consistent with established criteria for assessing nursery seedling quality based on height, diameter, and biomass allocation (Dickson *et al.*, 1960; Abdul-Baki and Anderson, 1973) ^[1, 9].

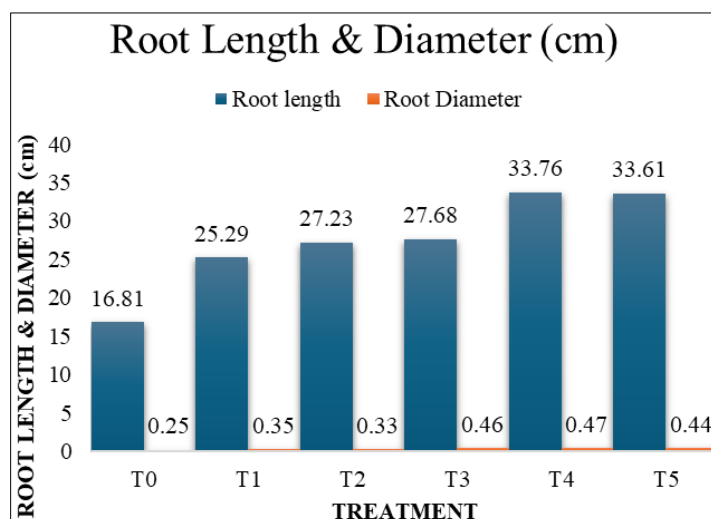


Fig 8: Effect of different pre-sowing treatments on root length and root diameter of *Terminalia catappa*.

Table 2: Effect of different pre-sowing treatments on seed germination behavior of *Terminalia catappa*

Treatments	No. of days to plant emergence	Germination percentage	Mean daily germination	Peak value	Germination value
T ₀	60.06	35.55	0.39	0.59	0.23
T ₁	33.80	53.33	0.59	1.57	0.94
T ₂	40.93	46.66	0.51	1.13	0.59
T ₃	18.86	77.77	0.86	3.70	3.20
T ₄	21	88.88	0.98	4.71	4.65
T ₅	22.86	66.66	0.74	2.91	2.17
SE(m)	0.11	1.04	0.01	0.03	0.05
CD	0.25	2.28	0.02	0.07	0.11
F - Test	S	S	S	S	S

Note: S = significant at the 5% level ($P < 0.05$).

Table 3: Effect of different pre-sowing treatments on plant growth behavior of *Terminalia catappa*

Treatment	Plant height			No. of leaves per plant			Shoot diameter			Root length at 90 DAS	Root diameter at 90 DAS
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS		
T ₀	0	3.62	13.62	0	0.86	6.26	0	0.08	0.23	16.81	0.25
T ₁	0	6.89	16.89	0	4.53	9.53	0	0.14	0.34	27.23	0.35
T ₂	0	5.54	15.54	0	2.53	7.53	0	0.13	0.32	25.29	0.33
T ₃	8.42	13.92	22.92	3.66	8.80	13.80	0.12	0.22	0.42	33.61	0.46
T ₄	10.91	16.41	26.41	3.86	10.20	15.13	0.13	0.23	0.43	33.76	0.47
T ₅	7.54	13.04	21.04	1.20	4.93	9.93	0.09	0.21	0.41	27.68	0.44
SE(m)	0.01	0.02	0.02	0.03	0.06	0.06	0.001	0.002	0.001	0.07	0.001
CD	0.02	0.04	0.04	0.07	0.14	0.14	0.003	0.005	0.002	0.15	0.001
F Test	S	S	S	S	S	S	S	S	S	S	S

Note: S = significant at the 5% level ($P < 0.05$)



Fig 9: Sowing of *Terminalia catappa* seed



Fig 10: Germinated seedlings of *Terminalia catappa*.



Fig 11: *Terminalia catappa* seedlings under different pre-sowing treatments

Conclusion

This study demonstrates that appropriate pre-sowing treatments can effectively overcome the physical seed dormancy of *Terminalia catappa* L. arising from its thick, woody endocarp. Among the treatments tested, soaking seeds in cold water for 24 hours (T_4) was the most effective, significantly enhancing physiological activation and raising the germination percentage to 88.88%, mean daily germination to 0.98%, and germination value to 4.65, while T_3 produced the shortest seedling emergence time (18.86 days). The T_4 treatment also produced the greatest plant height (26.41 cm), the highest number of leaves per seedling (15.13), the largest shoot diameter (0.43 cm), and the greatest root length (33.76 cm) at 90 days after sowing, indicating a marked overall improvement in seedling growth.

In contrast, the untreated control (T_0) exhibited delayed and non-uniform emergence together with prolonged physical dormancy, recording the longest time to germination (60.06 days), the lowest germination percentage (35.55%), and markedly stunted seedling growth. Other interventions, including a 48-hour cold-water soak (T_5) and a 5-minute hot-water soak at 70°C (T_3), did not match the consistency and effectiveness of the 24-hour cold-water soak. A 24-hour cold-water soak (T_4) can therefore be recommended as a cost-effective, practicable, and efficient operating standard for large-scale nursery management of this ecologically and economically important tropical tree species, supporting reliable seedling production and larger-scale reforestation efforts.

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