

Experimental Studies on Seed Germination and Seedling Establishment of *Terminalia tomentosa* (Roxb.) Wight & Arn

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Abstract

Terminalia tomentosa (Roxb.) Wight & Arn., a large deciduous tree of the family Combretaceae, is an important forest and timber species of the Indian subcontinent. Its propagation through seed is important for afforestation, reforestation, restoration of degraded forests and establishment of plantations. However, seed germination in *T. tomentosa* is often irregular and comparatively low, creating difficulties in large-scale nursery production. The present article reviews published information on seed germination, factors influencing germination and pre-sowing treatments of *T. tomentosa*, with particular emphasis on studies relevant to nursery production in Telangana. Published research indicates that seed characteristics, provenance, storage, temperature, season, moisture and pre-sowing treatment can substantially influence germination. Earlier investigations demonstrated considerable improvement following removal or scarification of the hard seed covering, while recent nursery research in Telangana evaluated gibberellic acid (GA₃), hot-water soaking, cow-dung treatment and sulphuric-acid scarification. Among the treatments tested, soaking seeds in hot water for 24 hours produced 71.11% germination, a 12-day germination period and 93.75% seedling survival. Seed weight and geographical origin have also been associated with differences in germination performance. Seasonal observations suggest that germination is more favourable during warmer conditions, whereas seedling survival may be greater during the rainy season. The available evidence demonstrates that appropriate pre-sowing treatment and nursery management can improve propagation efficiency. Further research is required to standardize seed collection, storage, dormancy-breaking treatments and nursery protocols for different provenances of *T. tomentosa*, particularly in the forest regions of Telangana.

Keywords: *Terminalia Tomentosa*; Seed Germination; Seed Dormancy; Seed Treatment; Hot-Water Treatment; GA₃; Seedling Survival; Nursery Propagation.

1. Introduction

Seed germination is the first major physiological stage in the establishment of a new plant and is influenced by seed characteristics and environmental conditions. Successful germination requires adequate moisture, suitable temperature, oxygen availability and physiological viability of the seed. In forest tree species, irregular germination can become an important constraint to nursery production and large-scale plantation establishment.

Terminalia tomentosa (Roxb.) Wight & Arn. belongs to the family Combretaceae and is an important deciduous forest tree distributed in different parts of the Indian subcontinent. The species has considerable timber and ecological importance and occurs in both moist and dry deciduous forest environments. Because of its value as a forest tree, efficient production of healthy planting material is important for regeneration, afforestation and restoration programmes.

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One of the important limitations in the propagation of *T. tomentosa* is its poor or irregular seed germination. Kale et al. (2023) identified the hard seed covering and low germination as important constraints for large-scale utilization of the species in afforestation, reforestation and commercial plantation programmes. Their nursery experiment at the Forest College and Research Institute, Mulugu, Telangana, demonstrated that suitable pre-sowing treatment can substantially improve germination and subsequent seedling establishment.

Previous studies have also demonstrated that germination is influenced by seed weight, geographical origin, storage period and temperature. A study involving three *Terminalia* species reported an average germination of 87% for *T. tomentosa* at a constant temperature of 25°C and found positive relationships between seed provenance, seed weight and germination in this species. Germination declined with increasing storage duration.

Therefore, understanding the germination behaviour of *T. tomentosa* and identifying suitable pre-sowing treatments are essential for efficient nursery production.

2. Materials and Methods

The present article was prepared as a **research-based literature synthesis** using published studies dealing specifically with seed germination, seed treatments, seed provenance, storage, seasonal effects and early seedling establishment of *Terminalia tomentosa*. The organization was developed in accordance with the seed-germination framework of the supplied reference article, which emphasizes seed characteristics, environmental factors, pre-sowing treatments and nursery establishment.

Published experimental observations were compared with respect to:

- germination percentage;
- germination period;
- germination energy;
- seedling survival;
- influence of seed weight and provenance;
- seasonal effects;
- pre-sowing treatments; and
- nursery growing conditions.

Particular attention was given to the experiment of Kale et al. (2023), conducted at Forest College and Research Institute, Mulugu, Telangana. The experiment used a completely randomized design with nine treatments and three replications. Mature seeds were sown in nursery beds using soil, sand and farmyard manure in a 2:1:1 ratio. The treatments included GA₃, hot-water soaking, cow-dung treatment, sulphuric-acid scarification and an untreated control.

No original experimental observations were generated for this article; therefore, the results presented below represent findings reported in the cited literature.

3. Results and Discussion

3.1. Germination behaviour of *Terminalia tomentosa*

Seed germination of *T. tomentosa* varies considerably depending on seed quality, treatment and environmental conditions. The presence of a hard seed covering can restrict water entry and delay the physiological processes necessary for germination. Consequently, untreated seeds may show delayed and irregular emergence.

Kale et al. (2023) reported 46.00% germination in their untreated control, whereas different pre-sowing treatments produced values ranging from 16.66% to 71.11%. The highest germination was obtained following hot-water soaking for 24 hours. This treatment also resulted in the shortest germination period among the tested treatments.

An earlier study on *T. tomentosa* reported that scarification treatments could improve germination, while removal of the endocarp produced particularly high germination. This evidence supports the view that the physical covering surrounding the seed is an important factor contributing to dormancy or delayed germination.

3.2. Effect of seed weight and provenance

Seed size and weight are important indicators of seed quality in many forest trees. Chand et al. (2012) studied different seed-weight classes of *T. tomentosa* and reported differences in germination and seedling growth. Seeds weighing 1–1.5 g showed the highest germination percentage, while heavier seeds produced greater seedling height, root length and biomass.

Provenance also influences germination. A study of three *Terminalia* species across different altitudinal origins found that seed weight of *T. tomentosa* increased with altitude and that germination percentage was positively associated with altitude. At a constant temperature of 25°C, average germination of *T. tomentosa* was approximately 87%. Germination declined with increasing storage duration, indicating that storage conditions and seed age are important considerations for nursery production.

3.3. Effect of temperature and season

Temperature regulates water uptake, enzyme activity and metabolic processes during seed germination. Published evidence indicates that *T. tomentosa* responds to seasonal environmental conditions.

Asha Krishna and Sujathamma (2021) evaluated seasonal effects on seed germination. Healthy dried seeds were soaked in water for 24–48 hours before sowing on a sand bed. The study reported the highest germination during summer, while seedling survivability was higher during the rainy season. No germination was recorded during winter in their study period, and overall germination remained below 50%.

These findings suggest that both germination and post-germination survival should be considered when selecting the appropriate nursery season. Warm conditions may favour germination, whereas adequate moisture during the rainy season may favour subsequent seedling establishment.

3.4. Effect of pre-sowing treatments

Pre-sowing treatments are particularly important for forest seeds with hard or impermeable coverings. Treatments may improve germination by increasing water absorption, facilitating gas exchange or modifying physical barriers surrounding the embryo.

Kale et al. (2023) compared nine treatments involving GA₃, hot water, cow-dung slurry, sulphuric acid and an untreated control. Hot-water soaking for 24 hours produced the highest germination percentage (71.11%), followed by 300 ppm GA₃ for 24 hours (64.44%). The 24-hour hot-water treatment also produced 93.75% survival and reduced the germination period to 12 days.

Table 1: Effect of selected pre-sowing treatments on seed germination of *Terminalia tomentosa*

Treatment	Germination (%)	Germination energy (%)	Germination period (days)	Survival (%)
GA ₃ 100 ppm, 24 h	52.22	43.33	18	82.97
GA ₃ 300 ppm, 24 h	64.44	25.55	22	87.93
GA ₃ 500 ppm, 24 h	46.66	40.00	13	85.71
Hot water, 24 h	71.11	24.44	12	93.75
Hot water, 12 h	27.77	36.66	14	84.00
Cow-dung treatment, 24 h	24.44	13.33	23	81.81
50% H ₂ SO ₄ , 2 min	16.66	14.44	24	73.33
50% H ₂ SO ₄ , 5 min	30.00	16.66	20	74.07
Control	46.00	30.00	21	83.33

Source: Kale et al. (2023).

Interestingly, the different acid treatments did not perform as well as hot-water treatment for germination percentage. The 50% sulphuric-acid treatment for two minutes recorded only 16.66% germination, while five minutes resulted in 30.00%. However, the five-minute acid treatment produced the highest shoot:root ratio (0.72) in the reported experiment.

3.5. Effect of storage

Seed storage is another important factor influencing germination. Seeds generally lose viability progressively during storage, although the rate of deterioration varies with species and storage conditions. For *T. tomentosa*, the study of seed provenance and storage reported an inverse relationship between storage duration and germination percentage. Storage at 4°C did not provide an improvement in viability retention compared with room-temperature storage in that investigation.

Consequently, collection of mature, healthy seeds followed by timely sowing may be preferable when facilities for long-term seed storage are limited.

3.6. Nursery establishment

Germination percentage alone is not sufficient for evaluating a nursery treatment. Survival and early seedling growth are equally important because the final objective is production of healthy planting material.

In the Telangana experiment, seeds soaked in hot water for 24 hours produced 93.75% survival, together with 25.17 cm root length, 14.40 leaves, 13.3 g root dry weight and 5 g shoot dry weight at the reported observation period.

The nursery substrate used in that experiment consisted of soil, sand and farmyard manure in a 2:1:1 ratio. This provides a useful documented nursery mixture for further evaluation, although additional experiments are necessary before recommending one substrate universally for all provenances and nursery conditions.

Table 2: Major factors influencing germination of *Terminalia tomentosa*

Factor	Reported influence	Evidence
Seed covering/dormancy	Hard covering can restrict germination; scarification can improve emergence	Kale et al., 2023
Seed weight	Different seed-weight classes differ in germination and seedling growth	Chand et al., 2012
Provenance/altitude	Germination varied with seed origin; positive relationship with altitude was reported	Thapliyal et al.
Temperature	25°C produced high germination in a provenance study	Thapliyal et al.
Season	Summer favoured germination; rainy season favoured survival in one study	Asha Krishna & Sujathamma, 2021
Storage	Longer storage reduced germination	Thapliyal et al.
Hot-water treatment	24-hour treatment produced 71.11% germination in a Telangana nursery study	Kale et al., 2023
GA ₃	Responses varied with concentration; 300 ppm produced 64.44% germination in one study	Kale et al., 2023
Sulphuric acid	Germination response was lower than hot-water treatment in the Telangana experiment	Kale et al., 2023
Nursery substrate	Soil:sand:FYM 2:1:1 was used successfully in the reported experiment	Kale et al., 2023

4. Conclusion

Seed germination is an important bottleneck in the nursery propagation of *Terminalia tomentosa*. Available research demonstrates that germination is influenced by seed characteristics, provenance, storage, temperature, season and pre-sowing treatment. The hard seed covering appears to be an important factor contributing to delayed or irregular germination.

Among the treatments evaluated in the recent Telangana nursery study, **hot-water soaking for 24 hours produced the highest germination (71.11%), shortest germination period (12 days) and highest survival (93.75%)**. GA₃ also improved germination at some concentrations, whereas the sulphuric-acid treatments used in that experiment produced lower germination percentages.

The available evidence supports the use of suitable pre-sowing treatment as an important component of *T. tomentosa* nursery production. However, germination responses may differ according to seed provenance, maturity, storage history and environmental conditions. Further controlled studies should therefore evaluate different seed sources of Telangana, seed maturity, storage duration, temperature, scarification intensity and combinations of water soaking and growth regulators. Such studies would help develop a standardized nursery protocol for large-scale production of *T. tomentosa* planting material for afforestation, reforestation and forest restoration programmes.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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