Seed germination behaviour of *Terminalia paniculata* Roth (Combretaceae), an economically important endemic tree to peninsular India

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**ABSTRACT**

The present study was conducted to investigate the seed germination behaviour of *Terminalia paniculata*, a commercially important tree component of deciduous forests of Peninsular India. The study included the identification of maturity index to determine the optimum collection period of the most viable seeds with good seed longevity. Species are characterized by very low germinability and poor regeneration status. Observations were made throughout the flowering and fruiting period on selected matured trees. Seed viability was tested at various stages of maturity and seed longevity was evaluated. The results, indicated that the 16th week after anthesis with red-colored fruits recorded the maximum viability (2.60%) germination that shows it is the best period for the collection of seeds. Seed emptiness is very high in *T. paniculata* (4 to 2%) compared to other *Terminalia* species (low emptiness). Pre-sowing treatments was not effective in enhancing seed germination and viability. Seeds can be stored up to 6 months in an air-tight metallic container at 4°C and 45 ± 5% relative humidity. The results of the study can be taken as a reference for various other tree improvement programs and further studies.

**KEYWORDS:** Germination, Maturity Index, Flowering Murdah, Seed Emptiness, Seed Longevity

**INTRODUCTION**

*Terminalia* L. (Combretaceae), commercially important taxa with winged fruits, is distributed in tropical and sub-tropical regions mainly in semi-evergreen, dry and moist deciduous forests. It is well known for its timber and traditional medicinal uses. Sixteen species of *Terminalia* were reported from India, and among them 12 species from mainland including 2 exotics, 4 from Andaman and Nicobar Islands, India (Gangopadhyay & Chakrabarty, 1997). *Terminalia paniculata* Roth is one of the multipurpose tree species endemic to Peninsular India and is distributed in Karnataka and Kerala. Massive fruiting in the deep red color of the species during the summer gives red coloration to the canopy and which leads the naming Flowering Murdah (Figure 1). Normally the tree grows up to 30 m height and more than 2.50 m diameters at breast height and distribution ranged from 800- 1200 MSL (Pillai, 2017). Wood is commonly used for construction, agricultural implements, boat building, plywood, blackboards, packing cases, and non-wood products are used for drug preparation, tannins, gums, oils, fodder and certain organic compounds (Narayanan et al., 2011; Nazma et al., 1981; Trotter, 1959). FAO, Botanical Garden Conservation International and several other agencies listed *T. paniculata* as one of the common commercially important tree species in India (FAO, 1984; Mark et al., 2014; Nair, 1971; Nazma et al., 1981; Trotter, 1959).

The population of the species is declined due to low regeneration status followed by anthropogenic activities especially massive felling of the trees for various wood and non-wood products (Pillai, 2017; Rani & Swaminath, 1999). Seed emptiness and poor seed germination are the general characteristic feature of the *Terminalia* genus and are very high in *T. paniculata* (Chacko et al., 2002). Low regeneration status of *T. paniculata* is due to high seed emptiness, poor seed germination, and climatic factors such as rain, temperature and moisture, which affect declining of the tree population (Chacko et al., 2002; Murali, 1997; Pillai, 2017). Population management and conservation of species are essential due to its multipurpose usage and endemicity. For the conservation of *T. paniculata* in the native range, detailed
knowledge on seed characteristics and analysis regarding seed quality parameters is needed. The information on seed behavior includes seed maturation, viability and seed longevity. Keeping all these factors in view, the present study was carried out to full-fill the above-mentioned objectives.

MATERIALS AND METHODS

Study Area

Maturity index analysis conducted in Peechi Forest Range of Peechi Wildlife Division of Kerala have an area of 126.73 sq. km. Peechi is bordered with Thrissur and Nenmara Divisions in the northwest and northeast side respectively and Chalakkudy Division and Chimmony Wildlife Sanctuary in the southern side (N 10° 26'-10° 40'; E 76° 15'-76° 28'). Seed germinability, viability and longevity studies conducted by using the seeds collected from Karulai Forest Range of South Nilambur Division, Kerala have an area of 265.61 sq. km. Karulai is bordered with North Nilambur Division in the north, Kalikavu Range in the west and Tamil Nadu in the southeast side (N 11° 14'-11° 23'; E 76° 19'-76° 34'). Laboratory experiments were conducted at Kerala Forest Seed Centre, Thrissur, Kerala, India.

Maturity Index

Thirty mature trees of T. paniculata were randomly selected from the study area for detailed investigation. Total height and circumference of trees ranging from 2.35–3.68 m ($\bar{x}$ = 29.67 m) and 22–34 m ($\bar{x}$ = 3.15 m) respectively and crown dimensions such as crown diameter and crown length ranging from 12–26 m ($\bar{x}$ = 19.6 m) and 10–17 m ($\bar{x}$ = 12.4 m) respectively. Ten inflorescences from each tree were selected, marked, and labelled during flowering initiation as per standard protocol developed by Walton et al. (2016). Periodical (weekly) observations were done from the period of fruit initiation up to mature fruit fall initiation covering the entire fruiting phenophases. Fruits were collected weekly during different stages of fruiting phenophases and documented the details like color of drupe and seed using the Munsell soil color chart (Reeder et al., 2014) and period of collection. Fruit characteristics such as fruit fresh mass, fruit dry mass, fruit large wing length, fruit large wing width and fruit small wings length were also documented. Shimadzu digital analytical weighing balance is used for estimating the fruit mass and Mitutoyo absolute digital Vernier Caliper is used for measuring the fruit large wing length, width and small wings length.

Seed Germinability

Seeds of T. paniculata were directly collected from thirty matured trees from the study area during 10th (when maturation starts) to 25th weeks (after fruit fall) after fruit set with an interval of one week. Fruit/seed was processed and tested for different seed parameters such as seed weight (number of seeds per kg), moisture content (MC %), seed viability and seed longevity. The MC of seeds was estimated by hot air oven-dry method (dry seeds in hot-air oven for 1 hr at 130°C) as per ISTA rules (ISTA, 2005).

Seed Viability and Longevity

Data were documented for each stage of fruit development and determined maturity index and optimum time for seed collection. Seeds from the 16th week after fruit setting were collected periodically (weekly), determined MC% and tested viability in terms of rapid viability test (cutting test using seed cutter) and germination test. Different pre-sowing treatments were applied to study the treatment effect on seed germination. Germination trials were conducted in germination trays filled with vermiculite as media.

The treatment details are as follows:
1. Control (without any treatment)
2. Seeds soaked in water for 12 hrs
3. Seeds soaked in water for 24 hrs
4. Seeds soaked in water for 48 hrs
5. De-winged seeds soaked in water for 12 hrs
6. De-winged seeds soaked in water for 24 hrs
7. De-winged seeds soaked in water for 48 hrs

The seeds were soaked in tap water and a germination test was conducted as per ISTA (2005) rules. Treated seeds (n = 1000 x 8) were taken from each treatment and placed on wet vermiculite media in plastic trays (30 x 40.5 x 7 cm) and kept under laboratory conditions. Observations on seed germination like the initial day of germination, speed of germination were recorded throughout the germination period and the end of the period, the number of normal seedlings in each replication was counted and the germination was expressed in percentage (ISTA, 2005). Cleared seeds were stored under cold (4°C) and ambient conditions in an air-tight plastic container for the study of seed longevity. Germination trials were conducted with monthly intervals with the stored seeds till the seeds express zero viability to estimate seed life span (Rajjou & Debeaujon, 2008). Data were recorded from the initial to the final day of seed
germination and determined different germination parameters as per the standard methods (Xu et al., 2016).

Analysis

Seed moisture content and viability from 11th to 25th week were analysed according to the ordinary least square regression (r) analysis (Wang et al., 2011). The effects of pre-sowing treatments were evaluated by Analysis of variance (ANOVA). For easier calculation and to explore the possible variation within the samples, statistical software PAST was used.

RESULT AND DISCUSSION

Maturity Index

Table 1 describes the colour of fruits/seeds, MC and germination per cent recorded during 11 – 25th week after seed setting. The developmental stage started with green coloured fruit with white-coloured non-viable seeds. From the 11th week after anthesis/seed setting, the greenish-red fruits have viable light brown seeds. Seed moisture content (4.69 ± 0.8%) and germinability (1.52 ± 0.76%) exhibited a slight increase up to 16th week and decreases afterwards. Seed moisture content and germinability exhibited a slight increase up to 16th week and decreases afterwards. Maximum moisture content and germinability noticed during the 16th week after fruit setting (59% MC and 2.60 ± 0.1% germination). The observation revealed that the seeds exhibited viability only up to 24th week and appears in dark red fruits with dark brown seeds. Sixteenth week was characterized by HUE 10R 4/6 red-coloured fruits with the help of the Munsell Soil Colour Chart. Morphological characteristics of fruits during the 16th week of fruit development is as follows - fruit colour (HUE 10R 4/6 red), fruit fresh mass (0.1849 ± 0.019 g), fruit dry mass (0.0370 ± 0.005 g), fruit large wing length (21.44 ± 1.16 mm), fruit large wing width (12.93 ± 0.79 mm), and fruit small wings length (14.66 ± 2.34 mm).

Seed Viability

Seed germination graph plotted against the moisture content and ordinary least square regression analysis revealed that there is a significant strong positive correlation (r² = 0.80756; p = 0.001) between the variables (Figure 2). The seed germination rate of different treatments was varied from 2.40 to 2.63% (Figure 3) and the maximum germination rate (2.63 ± 0.58%) was recorded in water soaking pre-sowing treatment for 24 hours (Table 2) but the effect of pre-sowing treatments found to be non-significant among the treatments. The study revealed that the germination initiated on the 14th day and required 21-22 days for completion.

Seed Longevity

Seeds of T. paniculata were able to maintain viability up to 6 months under cold condition (4°C with 45 ± 5 % RH) in an air-tight plastic container. However, a gradual decline from 2.60 ± 0.06 % to 0.20 ± 0.1 % of seed viability was observed during 6 months after storage (Figure 4). Table 3 depicts the longevity of seeds under storage. Seeds show 99.80% futile rate after six months under cold storage condition.

The size and weight of the seeds of T. paniculata are very small compared to other species of the genus-T. tomentosa, T. arjuna, T. bellerica, T. catappa, T. chebula, etc (Chacko et al., 2002). The present study showed that the size of the fruit is 6.1 ± 2.07 g and one kilogram contains 18,216 ± 6,872 fruits with mean moisture content is 46.4%. Seed dispersal of T. paniculata is anemochorous
like *T. arjuna* and *T. tomentosa* due to its winged fruit character. *T. paniculata* is characterized by high seed emptiness compared to associate tree species such as *Grewia tilifolia*, *Lagerstroemia microcarpa*, *Tectona grandis*, *Pterocarpus marsupium*, *Xyla xylocarpa*, etc (Chacko et al., 2002). Pre-sowing treatments are generally used to enhance seed germinability and speed of germination. There were different treatments applied to enhance germinability in *Terminalia* such as water soaking, scarification, hot water, acid scarification, hormone application, de-pulping, etc (Hossain et al., 2005; Hossain et al., 2014; Likoswe et al., 2008; Mewded et al., 2018). The application of 6 pre-sowing treatments in *T. paniculata* resulted that the pre-treatments are futile. Germinability of *T. paniculata* in natural conditions is very low (<1%) due to seed emptiness and high pest infestation and in laboratory conditions is 2.60% (Chacko et al., 2002). Storage study of the species confirmed that under cold conditions in an air-tight container, seed longevity shall be extended up to 6 months. Compared to other *Terminalia* species (360 days) or other associate winged species such as *Pterocarpus marsupium* (360 days), *Swietenia macrophylla* (360 days) and *Dalbergia latifolia* (360 days), seed longevity period is very low (Murali, 1997; Tompsett, 1986).

The rate of seed emptiness is very high in *T. paniculata* compared to other species belongs to *Terminalia* (Chacko et al., 2002). Seed emptiness is very less in *T. arjuna*, *T. bellerica*, *T. catappa*, *T. chebula* and their germinability is 61%, 85%, 80%, 60% respectively (Chacko et al., 2002). There are sixteen species of *Terminalia* are distributed in India, four of them are producing winged fruits including *T. paniculata*. Earlier studies confirmed that de-winging is the best pre-treatment of seed germination of winged seeds including in the case of *Terminalia* (Pillai & Chandrasekhara, 2011; Zoysa & Ashton, 1992). The results of the present study showed that the rate of seed germination varied between treatments (2.40 to 2.60%) and the differences were not statistically significant. Germination pattern showed that maximum germination rate was (2.60%) in water soaking treatments for 24 hours and about 21-22 days were required for completion of germination. Figure 3 shows the influence of pre-sowing treatments on *T. paniculata* seed germination. Lines on the top of the bars indicate the standard error of the sample. C: control; 12WS: 12 hr water soaking; 24WS: 24 hr water soaking; 48WS: 48 hr water soaking; 12DWS: 12 hr dewinged water soaking; 24DWS: 24 hr dewinged water soaking. Figure 4: Influence of storage time on *T. paniculata* seed germination. Number 0 is the initial germination after collection.

### Table 3. Pattern of seed longevity of *T. paniculata* under storage

| Sl. No. | Storage period (in months) | Germination (%) | Futile (%) | Difference in Germination (%) |
|--------|--------------------------|----------------|------------|-------------------------------|
| 1.     | 0 (fresh seeds)          | 2.6 ± 0.06     | 97.4       | -                             |
| 2.     | 1                        | 2.4 ± 0.06     | 97.6       | -0.2                          |
| 3.     | 2                        | 1.7 ± 0.06     | 98.3       | -0.7                          |
| 4.     | 3                        | 1.2 ± 0.15     | 98.8       | -0.5                          |
| 5.     | 4                        | 0.9 ± 0.06     | 99.1       | -0.3                          |
| 6.     | 5                        | 0.6 ± 0.06     | 99.4       | -0.3                          |
| 7.     | 6                        | 0.2 ± 0.1      | 99.8       | -0.4                          |

The rate of seed emptiness is very high in *T. paniculata* compared to other species belongs to *Terminalia* (Chacko et al., 2002).
of seeds under storage and the seeds were able to maintain viability up to 6 months within the air-tight metallic container at 4°C. However, a gradual decline from 2.60 ± 0.06 to 0.20 ± 0.10 % of seed viability was noticed during the six months after storage at 4°C.

CONCLUSIONS

Study documented seed characteristics of *T. paniculata* such as maturity index, germination pattern and seed longevity. The study concluded that during the 16th week after fruit setting, fruits are red with maximum germinability. It is very easy to identify the best fruit collection period with the help of the Munsell Colour Chart than identifying the 16th week of fruit development. Germination studies concluded that 2.60% is the maximum germinability and pre-sowing treatments do not enhance the germination rate. However, water-soaking for 24 hours helps to improve seed germination and reduce the germination duration. Seed longevity study revealed that seeds shall be stored up to six months under cold condition in an airtight plastic container. Results of this study will be helpful for tree improvement programs and other research programs of the species and similar species.

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REFERENCES

Chacko, K. C., Pandalai, P. C., Seethalakshmi, K. K., Mohanan, C., Mathew, G., & Sasidharan, N. (2002). Manual of seeds, forest trees, bamboos and rattans. Kerala Forest Research Institute, Thrissur, Kerala, India. FAO. (1984). Intensive multiple use forest management in Kerala. FAO forestry paper 53. http://www.fao.org/docrep/015/ae264e/ae264e00.pdf

Gangopadhyay, M., & Chakrabarty, T. (1997). The Family Combretaceae of India subcontinent. *Journal of Economic and Taxonomic Botany*, 21, 282-364.

Hossain, M. A., Arefin, M. K., Khan, B. M., & Rahman, M. A. (2005). Effects of seed treatments on germination and seeding growth attributes of *Hoiriaki* (*Terminalia chebula* Retz.) in the nursery. *Research Journal of Agriculture and Biological Sciences*, 12(2), 135-141.

Hossain, M. A., Uddin, M. S., Shumi, W., & Shukor, N. A. A. (2014). Depulping of fruits and soaking the seeds enhances the seed germination and initial growth performance of *Terminalia belerica* Roxb. seedlings. *American Journal of Plant Sciences*, 5, 714-725.

ISTA. (2005). International rules for seed testing 2005. International Seed Testing Association, Bassersdorf, Switzerland.

Likoswe, M. G., Njoloma, J. P., Mwase, W. F., & Chilima, C. Z. (2008). Effect of seed collection times and pretreatment methods on germination of *Terminalia sericea* Burch. ex DC. *African Journal of Biotechnology*, 7(16), 2840-2846.

Mark, J., Newton, A. C., Oldfield, S., & Rivers, M. (2014). The international timber trade: A working list of commercial timber tree species. Botanic Gardens Conservation International, United Kingdom. p. 9.

Mewded, B., Lemessa, D., Negussie, H., & Berhanu, A. (2018). Germination pretreatment and storage behaviour of *Terminalia laxiflora* seed. *Journal of Forest Research*, 30(4), 1337-1342. https://doi.org/10.1007/s11676-018-0717-3

Murali, K. S. (1997). Patterns of seed size, germination and seed viability of tropical tree species in Southern India. *Biotropica*, 29(3), 271-279. https://doi.org/10.1111/j.1744-7429.1997.tb00428.x

Nair, N. R. (1971). Volume tables for the forest trees of Kerala. Government Press, Trivandrum, p.3.

Narayan, M. K. R., Mithunlal, S., Sujanapal, P., Kumar, N. A., Sivadasan, M., Alfarhan, A. H., & Alatar, A. A. (2011). Ethnobotanically important trees and their uses by Kattunaakka tribe in Wayanad Wildlife Sanctuary, Kerala, India. *Journal of Medicinal Plant Research*, 5(4), 604-612.

Nazma, Ganapathy, P. M., Bhat, K. M., Sasidharan, N., & Gnanaharan, R. (1981). A handbook of Kerala timbers. KFRI Research Report No. 9. pp. 207-208

Pillai, P. K. C. (2017). Demographic studies of three selected species of Terminalias in the Kerala part of Western Ghats, South India. *Research Journal of Agriculture and Forest Science*, 5(5), 1-6.

Pillai, P. K. C., & Chandrasekhar, U. M. (2011). Regeneration study of selected Terminalias in Kerala. KFRI Research Report No. 414.

Reajou, L., & Debeaucour, J. (2008). Seed longevity: survival and maintenance of high germination ability of dry seeds. *Comptes Rendus Biologies*, 331(10), 796-805. https://doi.org/10.1016/j.crvi.2008.07.021

Rani, M., & Swaminath, M. H. (1999). Disturbance and diversity: The case study of *Terminalia paniculata*. *Myoforest*, 35(3), 249-258.

Reeder, A. I., Iosua, E., Gray, A. R., & Hammond, V. A. (2014). Validity and reliability of the Munsell soil color charts for assessing human skin color. *Cancer Epidemiology, Biomarkers & Prevention*, 23(10), 2041-2047. https://doi.org/10.1158/1055-9965.EPI-14-0269

Tompsett, P. B. (1986). The effect of temperature and moisture content on the longevity of seed of *Ulmas carpinitolia* and *Terminalia brasi*. *Annals of Botany*, 57(6), 875-883. https://doi.org/10.1093/oxfordjournals.aob.a087172

Trotter, H. (1959). The common commercial timbers of India and their uses. Government of India Press, Delhi. pp: 179-180.

Walton, D. A., Randall, B. W., Poinou, M., Moxon, J., & Wallace, H. M. (2016). Maturity indices of *Canarium indicum* (Burseraceae) nuts. *Acta Horticulturae*, 1109, 17-22. https://doi.org/10.17660/ActaHortic.2016.11093.9

Wang, Q., Zhang, T., Cui, J., Wang, X., Zhou, H., Han, J., & Gislerum, R. (2011). Path and ridge regression analysis of seed yield and seed yield components of Russian wildrye (*Poastrachys juncea* Nevski) under field conditions. *PloS One*, 6(4), e18245. https://doi.org/10.1371/journal.pone.0018245

Xu, Y., Cai, N., He, B., Zhang, R., Zhao, R., Zhao, W., Mao, J., Duan, A., Li, Y., & Woeste, K. (2016). Germination and early seedling growth of *Pinus densata* Mast. provenances. *Journal of Forest Research*, 27(2), 253-294. https://doi.org/10.1007/s11676-015-0186-6

Zoyza, N. D., & Ashton, P. M. S. (1992). Germination and survival of *Shorea trapeziformia*: Effects of dewining, seed maturity and different light and soil microenvironments. *Journal of Tropical Forest Science*, 4(1), 52-63.