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RESEARCH ARTICLE

Sequential advancement in germination of commercially important lesser-known tree species, *Mallotus philippensis* (Lam.) Mull. Arg.

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Abstract

The present trial was undertaken to enhance the germination of a commercially important lesser-known tree species, *Mallotus philippensis* under nursery condition at College of Forestry, Navsari Agricultural University, Navsari, Gujarat, India during 2025. The experiment comprised of 7 media treatments *viz.* soil, sand, cocopeat, vermiculite, soil + sand (1:1), soil + sand (2:1) and soil + sand (1:2) filled in perforated trays and arranged in completely randomized design with three repetitions. Seeds pre-treated by soaking in water for 12 hr followed by GA_3 (50 ppm) for 60 min were sown and the germination parameters were recorded up to 30 days after sowing. The media treatments significantly influenced the germination attributes in *M. philippensis* at 30 days after sowing. Sand medium recorded the maximum germination (75.00 %), mean daily germination (2.50), higher germination rate index (55.15) and germination value (8.39) while soil + sand (1:2) exhibited the highest peak value (3.62) and took the minimum mean germination time (14.63 days) to germinate. In the trial, sand emerged as the best germination medium demonstrating a strong potential for production of large-scale and quality seedlings of *M. philippensis*. Further, the seed germination of *M. philippensis* enhanced sequentially from 30.67 % to 75.00 % as evident from the present trial.

Keywords: germination; *Mallotus philippensis*; nursery; sand medium

Introduction

The genus *Mallotus* belongs to family Euphorbiaceae, comprising 150 species which are extensively distributed in the world's tropical as well as subtropical regions with around 20 species found in India (1, 2). *Mallotus philippensis* is commonly known as 'Kamala' (Trade name) and 'Kampillaka' (Sanskrit), 'Sinduri' (Telugu) and Monkey face tree in English (2, 3). It is typically a small to medium sized dioecious evergreen tree and can grow up to 25 m tall with a diameter up to 50 cm (2). In India, it is commonly found in the tropical and subtropical areas including all over Punjab, Uttar Pradesh, West Bengal, Assam and throughout the western ghats (3-5). Kamala is reported to occur at an elevation upto 1600 m above mean sea level and grows best in areas where annual daytime temperature is in the range of 25-34 °C (tolerates 7-45 °C) and prefers a mean annual rainfall in the range of 1000-2500 mm (tolerates 600-5000 mm). It withstands a wide range of soil types, including limestone and rocky land, acid, infertile soils with soil pH in the range of 5-6.7 (tolerates 4.5-7.5) is found to be best for its growth (3, 6). This tree thrives well in full sunlight but also tolerates a considerable amount of shade. Additionally, it is frost hardy, drought resistant and sensitive to fire. It coppices very effectively and can produce root suckers; however, the growth is very slow (7). Phenological observations indicate that flowering occurs from March to April, while fruits normally ripen in July and August (8, 9).

Kamala is a multipurpose, medicinally important plant belonging to a large genus of woody plants (10). Various parts of *M. philippensis* including the stem, bark, leaves, roots and capsules, as well as the hairs covering its fruits, have been utilized for centuries in Ayurvedic, Unani, Arabic and Chinese traditional medicine systems as antibacterial, anthelminthic, antifilarial, immunoregulatory, antiparasitic, etc. (11). It was formerly used to dye silk and woollen fabrics to bright orange colour. Kamala seed oil is a well-known substitute for Tung oil (*Aluerites* spp.) used to make quick drying paints and varnishes (12, 13). It is regarded as a lesser-known tree species that has not yet been assessed for the IUCN Red list; however, in Gujarat, it is classified as an 'Endangered' species, indicating a pressing need for conservation efforts (5, 14). Germination rates are generally low, often due to drought stress and insect damage. The plant is typically propagated through seeds and germination is approximately 5 % in 65 to 82 days in natural conditions due to physical plus physiological seed dormancy (4, 15). Mature seeds of Kamala are dispersed during the hot summer months (April-May), typically remaining on the forest floor and germinated in the following rains in July. To withstand prolonged exposure to high temperatures and prevent desiccation injury, the seeds develop a pronounced hard seed coat dormancy. Such physical dormancy is common across numerous tropical species and arises from both genetic and environmental influences. In *M. philippensis*, the impermeable seed coat restricts water imbibition, thereby limiting moisture availability to the embryo and preventing germination until conditions become favourable (13). However, there is a lack of comprehensive studies on the dormancy and germination status of Kamala (3, 12).

The availability of good quality nursery stocks is a key factor in the determination of success of any plantation programme. The subsequent field growth and productivity of plants depend upon the production of good and healthy nursery raised seedlings which also helps to meet the tree plantation target (4, 5, 16). Direct sowing of seeds through artificial regeneration has given poor results, whereas nursery grown seedlings showcase greater resilience to harsh growth conditions, having greater survival rate and swifter growth compared to directly sown seeds in the field (4, 17). A major hindrance in forestry seeds propagation must be the low germination rates. Various media are used to enhance seed germination in tree species based on their specific properties. Identification of suitable germination media is important for a particular tree species to enhance its production by reducing the number of days for the seeds to germinate. *Mallotus philippensis* is an endangered, underutilized, slow growing tree species having poor germination rate and low population with multiple uses (4, 5, 18). Moreover, very less research approach for germination and its attributes were carried out for the species. Thus, this study aimed to evaluate the effectiveness of different germination media in improving germination percentage and associated parameters in *M. philippensis*.

Materials and Methods

The trial was conducted at College of Forestry, Navsari Agricultural University, Navsari, Gujarat, India during 2025. For the trial, ripened fruits were collected from the mature trees having well developed crown distributed at Gadat (20.85°N, 72.98°E), Gandevi, Navsari, Gujarat, India. Collected fruits were dried under shade for 5 to 6 days and seeds were separated manually after bursting the fruits. From these seeds, dark brown to black coloured round shaped uniform good seeds were selected. In the trial, various media treatments *i.e.* soil (T_1), sand (T_2), cocopeat (T_3), vermiculite (T_4), soil + sand (1:1- T_5), soil + sand (2:1- T_6), soil + sand (1:2- T_7) were employed in a completely randomised design (CRD) with 3 repetitions. The Electrical Conductivity (EC) of the different media were 0.20 dS/m (soil), 0.03 dS/m (sand), 0.05 dS/m (cocopeat) and 0.08 dS/m (vermiculite). Likewise, the pH of the different media was 7.52 (soil), 7.11 (sand), 4.66 (cocopeat) and 9.34 (vermiculite).

The media mixtures were homogenized and allowed to stabilize for 2 days. The composite sample from the overall mixture was drawn for each treatment and the media was filled into perforated trays of size 37 cm × 27 cm × 7 cm which were kept in the net house for germination. For germination trial, the best pre-sowing seed treatment was followed *i.e.* seeds of Kamala were soaked in normal water for 12 hr followed by soaking in GA_3 solution at the rate 50 ppm for 60 min were sown (4). In the trial, 100 seeds per treatment per repetition (300 = 100 × 3, in total of 2100 seeds) were sown in the trays (at the rate 100 seeds per tray) and overhead irrigation was provided once daily. Observations were taken at fixed intervals starting from the day after sowing and continued up to 30 days on daily basis. Various germination parameters such as Germination Percentage (GP), Mean Daily Germination (MDG), Peak Value of Germination (PV), Germination Value (GV), Mean Germination Time (MGT) and Germination Rate Index (GRI) were recorded at 30 Days After Sowing (DAS) and calculated as per the standard formulae given below.

Germination attributes

Germination percentage

Seeds germinated in each treatment were counted on daily basis and recorded for up to 30 days. From this data, germination percentage was calculated as:

$$\text{Germination Percentage} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100 \quad \text{(Eqn.1)}$$

Mean daily germination (MDG)

It shows the average number of seeds germinated per day and the value of it is unitless (19).

$$\text{Mean Daily Germination} = \frac{\text{Cumulative germination per cent}}{\text{Total number of days taken for germination}} \quad \text{(Eqn.2)}$$

Peak value of germination (PV)

It is calculated based on the formula given below and the value of it is unitless (19).

$$\text{Peak Value} = \max\left\{\frac{G_1}{T_1}, \frac{G_2}{T_2}, \frac{G_3}{T_3}, \ldots\ldots\ldots \frac{G_n}{T_n}\right\} \quad \text{(Eqn.3)}$$

Where, G_1, G_2, G_3……G_n are cumulative germination percentage in the n^{th} time interval and T_1, T_2, T_3,……T_n are the time from the start of experiment to n^{th} interval.

Germination value (GV)

It is a composite value that combines both germination speed and total germination which provides an objective means of evaluating the results of germination test. It is calculated by using formula given below and the value of it is unitless (19).

$$\text{Germination Value} = \text{Peak Value of Germination} \times \text{Mean Daily Germination} \quad \text{(Eqn.4)}$$

Mean germination time (MGT)

Mean Germination Time is expressed in day and calculated by using formula as below.

$$\text{Mean Germination Time} = \frac{\Sigma\ \text{Maximum germination (\%) achieved} \times \text{particular day on daily count}}{\text{Total number of seed germinated}} \quad \text{(Eqn.5)}$$

Germination rate index (GRI)

It is enumerated by using following formula and expressed in value which is unitless.

$$\text{Germination Rate Index} = \frac{G_1}{T_1} + \frac{G_2}{T_2} + \frac{G_3}{T_3} + \ldots\ldots + \frac{G_n}{T_n}$$

(Eqn.6)

Where, G_1, G_2, G_3…Gn are daily germination percentage in the n^{th} day and T_1, T_2, T_3…Tn are the day at which germination was counted from the start of experiment to n^{th} interval.

Statistical analysis

The data obtained from the experiment were organized and tabulated in MS Excel and subjected to statistical analysis using OPSTAT software in experimental design and the means were separated using Duncan multiple range test at 5 % level of probability (20). Further, the sequential enhancement of germination of the tree species is overviewed and conclusion is drawn.

Results and Discussion

Germination and its attributes of *Mallotus philippensis*

The germination attributes of *M. philippensis* exhibited considerable significant variation among the various media treatments. The germination rate ranged from 65.67 to 75.00 %, with a mean value of 70.76 %. Among various media treatments, sand (T_2) achieved the highest seed germination rate of 75.00 %, comparable to cocopeat (T_3) and soil + sand (2:1- T_6) combination, both at 74.00 % ($p < 0.05$); in contrast, vermiculite (T_4) exhibited the lowest germination rate of 65.67 % (Table 1). Likewise, the MGT was observed to be lowest in the T_7- soil + sand (1:2) medium at 14.63 days ($p < 0.05$); conversely, it reached maximum of 20.19 days in the soil (T_1), yielding an overall mean of 16.51 days (Table 1). The GRI ranged from 34.37 to 55.92, with an overall mean of 48.72. The treatment comprising soil and sand in 1:1 ratio (T_5) had higher GRI of 55.92, comparable to that of sand (T_2) at 55.15 and soil + sand in 1:2 ratio (T_7) of 54.30 ($p < 0.05$); in contrast, the soil treatment (T_1) revealed lower GRI of 34.37 indicating slow and delayed germination in pure soil (Table 1).

Table 1. Influence of different media on GP (Germination Percentage), MGT (Mean Germination Time) and GRI (Germination Rate Index) of *Mallotus philippensis*

Treatments	GP	MGT	GRI
T_1: Soil	68.00^{cd}	20.19^{a}	34.37^{d}
T_2: Sand	75.00^{a}	15.70^{d}	55.15^{a}
T_3: Cocopeat	74.00^{ab}	17.46^{b}	45.83^{c}
T_4: Vermiculite	65.67^{d}	16.19^{cd}	45.86^{c}
T_5: Soil + sand (1:1)	70.67^{bc}	14.65^{e}	55.92^{a}
T_6: Soil + sand (2:1)	74.00^{ab}	16.72^{c}	49.58^{b}
T_7: Soil + sand (1:2)	68.00^{cd}	14.63^{e}	54.30^{a}
Mean	70.76	16.51	48.72
S.Em. (±)	1.25	0.20	0.67
C.D. at 5 %	3.78	0.60	2.03
C.V. (%)	3.05	2.09	2.38

Values with similar alphabets within a column are not significantly different. *S.Em: Standard Error of mean, C.D.: Critical Difference, C.V.: Coefficient of Variation

Likewise, the MDG varied between 2.19 and 2.50, yielding an overall mean of 2.36 reflecting uniformity in daily germination among treatments. Among various media treatments, sand (T_2) demonstrated the highest MDG of 2.50 and comparable to cocopeat (T_3), soil + sand (2:1- T_6) both of 2.47 and soil + sand (1:1- T_5) of 2.36 ($p < 0.05$) suggesting rapid initial germination; in contrast, vermiculite (T_4) exhibited the lowest MDG of 2.19 (Fig. 1). The GV ranged from 5.84 to 8.43, with a mean of 7.57. The combination of soil and sand (1:1 - T_5) exhibited the highest germination value (8.43) and at par with sand alone (T_2) with value of 8.39 ($p < 0.05$); meanwhile, soil alone (T_1) demonstrated the lowest germination value of 5.84 (Fig. 1). Conversely, the soil and sand mixture (1:2 - T_7) exhibited the highest peak germination value (3.62, $p < 0.05$), while the soil alone (T_1) demonstrated the lowest peak germination value (2.49), resulting in an overall mean of 3.16, as illustrated in Fig. 1.

Sequential development in germination of *Mallotus philippensis*

Numerous experiments were undertaken on *M. philippensis* to examine germination rates and to enhance various germination parameters in nursery stage. In nursery conditions, at the College of Forestry, NAU, Navsari, Gujarat, India, it was reported that among various pre-sowing seed treatments, the highest germination rate (48.67 %) was achieved by soaking *M. philippensis* seeds in normal water for 12 hr, followed by soaking in a GA_3 solution at 50 ppm for 60

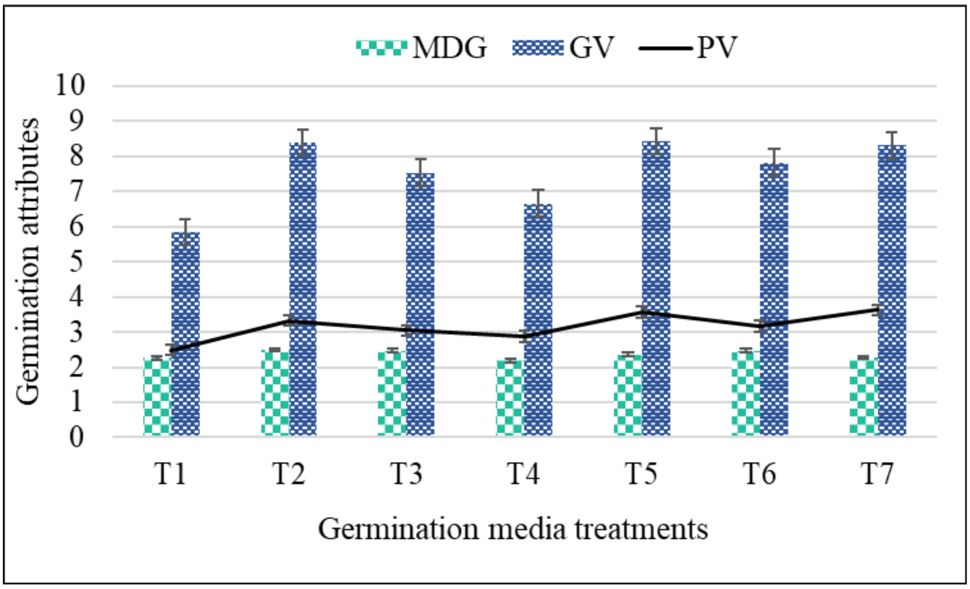

Fig. 1. Influence of different media on MDG (Mean Daily Germination), GV (Germination Value) and PV (Peak Value of Germination) of *Mallotus philippensis*.

min (21). Notably, without any pre-sowing seed treatments, seeds of *M. philippensis* grown in sand media exhibited a considerably higher germination rate of 30.67 % compared to other germination media (22). The current trial on the impact of growth media on germination parameters revealed a significant effect on seed germination in *M. philippensis*. Among the various growing media, sand demonstrated superior performance relative to the others, achieving the highest seed germination rate of 75.00 %. Fig. 2 illustrates the sequential progression of germination in *M. philippensis*.

Germination and its attributes of *Mallotus philippensis*

Among the various growing media, sand exhibited superior performance compared to others, with the maximum seed germination rate of 75.00 % and in other germination attributes of *M. philippensis*. Generally, the seed germination of a forest tree species tends to vary in different growing media. Seed germination is typically affected by intrinsic factors such as seed characteristics, dormancy and viability. Furthermore, extrinsic environmental factors, including substrate type, oxygen availability, water, light and temperature, significantly affect seed germination (5, 23, 24). The prompt and optimal germination of *M. philippensis* seeds can be ascribed to the elevated porosity of the sand medium, which facilitates seed imbibition and provides adequate aeration for rapid germination, hence enhancing oxygen diffusion crucial for vigorous respiration (5, 25). Furthermore, sand, because of its coarse texture and increased macroporosity, promotes unobstructed gaseous exchange between the germination media and the growing embryo. The germination rate is tightly linked to oxygen availability, which drives respiratory metabolism (26). Additionally, sand warms up more quickly, thereby enhancing biochemical processes that promote higher seed germination rates, especially relevant for species adapted to tropical climates (27). In addition to porosity, the maintenance of optimal temperature may significantly contribute to the observed maximum seed germination in sand media (24). These characteristics foster an ideal environment for seed germination and aid in maintaining seed viability (5). Thus, these characteristics of sand may enhance the efficacy of many germination parameters in *M. philippensis*.

Sand alone improves seed germination and its characteristics in *M. philippensis* and various forest tree species. The seeds of *M. philippensis* sown in sand media exhibited significantly superior germination metrics: maximum germination (30.67 %), mean daily germination (1.05), peak germination value (1.88), germination value (1.93) and germination rate index (3.10), while requiring the least germination duration (4.90 days) to sprout (5). Likewise, sand yielded the highest seed germination rates in *Jatropha curcas* and *Pongamia pinnata*; conversely, in *Dacryodes edulis*, sand media had a maximum germination rate of 100 % (25, 28). Furthermore, seeds of *Santalum album* sown in sand media exhibited significantly superior germination parameters (29). Likewise, on sand medium, optimal germination characteristics were observed in *Stereospermum suaveolens*, *Senna fistula* and *Sterculia urens* (30–32). The advantageous qualities of sand certainly contributed to the improvement of germination attributes in *M. philippensis*.

The combination of sand with soil and other germination media, such as cocopeat, vermicompost and farm yard manure (FYM), also yielded enhanced seed germination and its characteristics in forest tree species. The highest seed germination rate (77.33 %) and the shortest germination period (27.11 days) were observed in *Mangifera indica* cultivated in a substrate of soil, sand and FYM at a ratio of 2:1:1 (33). In a comparable manner, the highest germination (85.30 %) was observed in *Acer negundo* in a soil: sand: FYM ratio of 2:1:1; conversely, *Emblica officinalis* exhibited maximum germination (86.11 %) in a red earth, FYM, sand ratio of 2:1:1 according to references (34, 35). Furthermore, improved germination efficacy was seen in *Gmelina arborea* in a soil: sand: vermicompost ratio of 2:1:1 and *Semecarpus anacardium* in vermicompost + sand + pond soil ratio of 1:1:1 (36, 37). Across diverse species, germination media mixtures containing sand consistently outperform soil-only media in terms of improved germination attributes such as in forest tree species like Allepo pine, *Vitellaria paradoxa*, *Pterocarpus santalinus*, *Syzygium cumini*, *Pinus gerardiana*, *Juglans regia*, *Schleichera oleosa*, *Sterculia foetida* and *Gmelina arborea* (38-46).

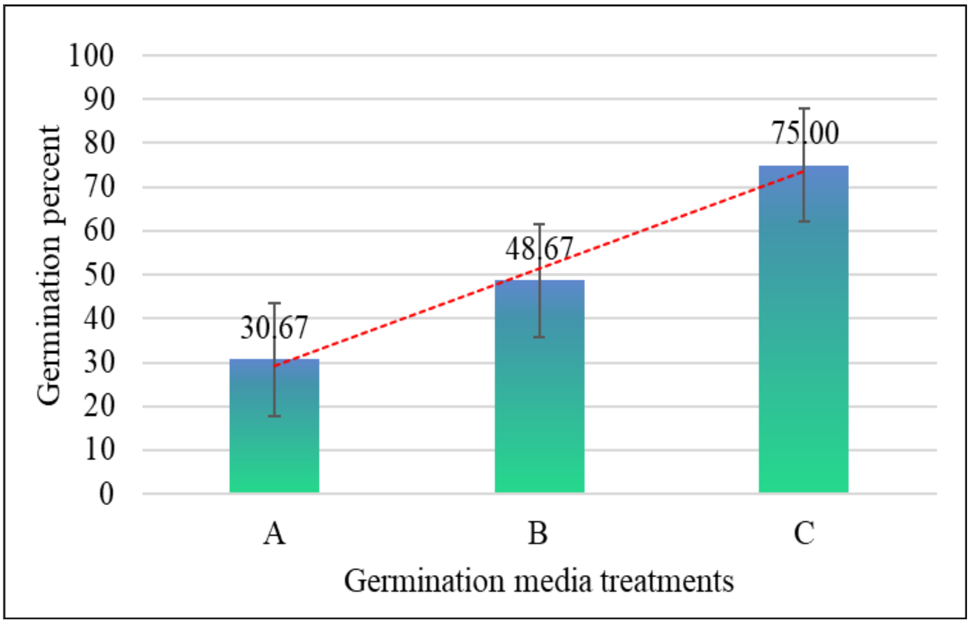

Fig. 2. Sequential advancement in germination percentage of *Mallotus philippensis* under different treatments [A- seeds sown in sand media (22); B- soaking seeds in water for 12 hr followed by GA_3 (50 ppm) for 60 min (21) and C- treatment A + B].

Sequential development in germination of *Mallotus philippensis*

The germination percentage of *Mallotus philippensis* exhibited significant variation among the three treatments assessed. Seeds sown directly in sand media (Treatment A) exhibited a germination rate of 30.67 %, suggesting that sand alone can facilitate germination, albeit with limited efficacy (22). Seeds subjected to pre-sowing treatments, specifically soaking in water for 12 hr followed by GA_3 (50 ppm) for 60 min (Treatment B), exhibited a significant enhancement, attaining 48.67 % germination (21). This improvement may be ascribed to the softening of the seed coat during water soaking and the function of GA_3 in alleviating physiological dormancy and promoting embryo development. Treatment C, which involved both pre-seeding treatment and sowing in sand, achieved the greatest germination rate of 75 %. This study builds upon previous research by combining the most effective pre-sowing treatment with the optimal medium as sand (21, 22). This integrated method yielded a significantly improved germination rate of 75 %, markedly surpassing the figures recorded under natural conditions of 5 % and those achieved in nursery conditions with either pre-sowing treatments alone or media treatments alone (15, 21, 22). Sand presumably promoted imbibition and aeration, but GA_3 expedited metabolic activation, resulting in rapid and improved germination. The progressive rise in germination from A → B → C clearly indicates that the combination of physical (germination media) and physiological (seed treatment) treatments substantially enhances germination efficiency in *M. philippensis*.

Conclusion

Sand proved to be the most effective medium for improving overall germination efficiency in *M. philippensis*, exhibiting the highest germination percentage and improvement in other parameters. The seeds of *M. philippensis* soaked in normal water for 12 hr followed by soaking in GA_3 solution at the rate 50 ppm for 60 min with sand media significantly improved germination efficiency. These findings provide valuable insights for large scale production of quality seedlings of *M. philippensis* in nursery condition supporting restoration and propagation initiatives for this underutilized yet economically valuable tree species.

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Authors' contributions

SB, LB, AAM and SAH contributed to the conceptualization of the study and the research design. SMP developed the methodology, while MHP was responsible for supervision and validation. SB, ADT and PDT conducted data collection and performed the statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: All authors who contributed to the preparation of this manuscript do not have any conflict of interest.

Ethical issues: None

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