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Branch Size-Mediated Variation in Epicormic Shoot Emergence and Growth in *Melia dubia Cav.*

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Abstract

Melia dubia is a fast-growing, short-rotation tree species widely cultivated for plywood, pulp, and biomass production; however, large-scale planting is constrained by poor seed germination and genetic variability. Although epicormic shoot-based propagation offers a reliable clonal alternative, the influence of branch size on epicormic shoot induction and rooting under hormone-free conditions has not been adequately quantified. The present study evaluated the effect of branch diameter and length on epicormic shoot production and propagation success. Branches were categorized into four treatments based on two diameter classes (1.0-1.5 cm and 3.0-5.0 cm) and two length classes (30 and 90 cm) and maintained under mist chamber conditions. Epicormic shoot emergence, growth attributes, and shoot vigour index were recorded after 50 days, followed by rooting of shoots in sand medium. Thinner branches exhibited earlier sprouting and higher shooting percentage but produced weak shoots that failed to root. In contrast, larger branches produced delayed sprouting but generated more vigourous shoots with higher shoot vigour index, superior rooting percentage (83.33%), complete survival, and enhanced root and shoot growth. Therefore, larger branches are the most suitable source material for efficient epicormic shoot-based clonal propagation of *Melia dubia*.

Key words: Epicormic shoots, Branch diameter, Clonal propagation, *Melia dubia*, Rooting percentage, Hormone-free propagation

Melia dubia Cav. is a short-rotation, fast-growing tree species that has gained considerable prominence as an industrial raw material for the plywood, pulp, and biomass-based energy sectors in India and other tropical regions [1]. Its exceptional growth rate, adaptability across a wide range of agro-climatic zones, and compatibility with agroforestry systems make it an economically viable alternative to conventional timber species. The species is increasingly preferred by farmers due to its short rotation period of 6-8 years, minimal pest incidence, low shading effect on intercrops, and substantial potential for carbon sequestration. In addition, *Melia dubia* responds favourably to silvicultural and management interventions, further enhancing its commercial appeal [2].

Despite its economic importance, large-scale commercial propagation of *Melia dubia* remains constrained by several seed-related limitations, including low germination percentage, short seed viability, and high genetic heterogeneity among seedlings. Although the species is traditionally propagated through seeds, natural germination is reported to be as low as ~8.8% [3]. Vegetative propagation therefore represents a more reliable strategy for producing true-to-type planting material in *Melia dubia*. The species exhibits strong coppicing ability, reflecting its inherent regenerative potential [4].

In *Melia dubia*, branch size strongly governs epicormic shoot emergence and subsequent growth, with medium-sized branches (about 2–5 cm diameter) showing the highest number, vigour and survival of shoots compared to very small or very large branches. Small branches possess limited carbohydrate reserves and low dormant bud density, resulting in weak, short-lived shoots, while large branches have thick bark, buried or suppressed buds and strong apical dominance that delays or reduces sprouting. Medium branches maintain an optimal balance of stored carbohydrates, cambial activity and a high cytokinin-to-auxin ratio after pruning, which promotes rapid bud activation, longer shoots, greater leaf area and better survival. Consequently, for coppicing, pollarding or canopy recovery in agroforestry systems, retaining branches of 2–5 cm diameter is ideal, although selective thinning of excess epicormic shoots is recommended to avoid knot formation and maintain timber quality.

Propagation through coppice and juvenile stem cuttings has been successfully standardized under nursery conditions. Juvenile coppice shoots of pencil thickness (0.5-1.0 cm

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diameter) responded effectively to auxin application, with IBA concentrations of 1000-3000 mg L^{-1}. Among rooting substrates, sand proved superior, recording rooting percentages of approximately 80%, followed by coir pith (60%), while potting mixtures and vermiculite were comparatively less effective [5]. Standardization of epicormic shoot-based propagation has enabled large-scale multiplication while maintaining genetic fidelity, uniform growth, and superior field performance.

Although epicormic shoot–based propagation is increasingly recognized as a reliable method for large-scale clonal multiplication of *Melia dubia*, the influence of branch size on epicormic shoot initiation, shoot vigour, and subsequent rooting success has not been quantitatively evaluated, particularly under hormone-free conditions. However, despite its practical relevance, the role of branch size in regulating epicormic shoot initiation, shoot vigour and subsequent rooting success has received little quantitative attention, especially under hormone-free conditions that are essential for developing low-cost nursery technologies. Branch diameter governs the density and viability of dormant buds, availability of stored carbohydrates, vascular connectivity and the hormonal balance between auxins and cytokinins, all of which directly influence both the number of shoots produced and their physiological quality. Medium-sized branches are likely to provide optimal conditions by maintaining sufficient reserves and a favourable cytokinin-to-auxin ratio after pruning, resulting in vigorous shoots with higher leaf area, thicker bases and improved endogenous rooting potential, whereas shoots derived from very thin or overly thick branches often suffer from poor establishment and reduced rhizogenic capacity. Without precise information on these size-dependent responses, nursery managers are forced to rely on trial-and-error approaches, leading to variable multiplication rates and inconsistent field performance. Systematic evaluation of branch size classes under hormone-free conditions is therefore critical for standardising epicormic shoot propagation protocols, lowering production costs, and ensuring uniform, high-quality clonal stock for sustainable industrial plantations and agroforestry programmes. Therefore, the present study is among the first to quantitatively evaluate the interaction between branch diameter, branch length, epicormic shoot development, and rooting performance in *Melia dubia* without exogenous hormone application. By examining distinct branch size classes, this study aims to identify an optimal branch size that ensures vigourous shoot production and efficient, sustainable vegetative propagation.

MATERIALS AND METHODS

The study was conducted under nursery conditions at Vellanikkara, Kerala, India, which experiences a subtropical climate. Healthy and disease-free *Melia dubia* Cav. Mature plantation-grown trees of uniform age were selected as donor plants. Branches were harvested during the active growth season to ensure optimal physiological responsiveness.

Harvested branches were categorized into four treatments based on branch diameter and branch length shown in (Fig 1), as detailed below:

Treatments	Branch diameter (cm)	Branch length (cm)	Fig. No.
1	1-1.5	30	1a
2	1-1.5	90	1b
3	3-5	30	1c
4	3-5	90	1d

The experiment was conducted using a completely randomized design (CRD), with each treatment consisting of six replications. The branches were planted vertically under mist chamber conditions with intermittent misting of 10 seconds at 20-minute intervals from 10:00 am to 5:00 pm. No exogenous plant growth regulators were applied at any stage of the experiment in order to isolate the effect of branch size alone on epicormic shoot induction and growth.

a b c D

Fig 1 Branches representing (a) Treatment 1 (b) Treatment 2 (c) Treatment 3 (d) Treatment 4

The following observations were recorded to assess epicormic shoot emergence and growth:

- Days to first epicormic shoot emergence
- Shooting percentage (%)
- Number of epicormic shoots per branch
- Mean shoot length (cm)
- Mean shoot diameter (mm)
- Mean number of leaves
- Shoot vigour index

Except for days to first sprouting, all other parameters were recorded on the 50th day after planting. Shoot vigour was quantified using a Shoot Vigour Index (SVI), calculated as the product of shoot length, shoot diameter, and number of leaves. This composite index was adapted from earlier seedling vigour index concepts that integrate multiple morphological traits to assess overall propagule quality [6-8].

Epicormic shoots were harvested 50 days after planting, and planted in sand medium without any exogenous hormone treatment to evaluate their inherent rooting potential, following CRD. The shoots were watered daily. One month after planting, rooting percentage (%) was recorded, and within this period, the time taken for root emergence was also observed.

Rooted epicormic shoots were transplanted into a sand : soil : vermicompost mixture (1:1:1) and maintained under nursery conditions. These plants were grown for four months before final observations were recorded on the following parameters:

- Rooting percentage of epicormic shoots (%)
- Time taken for root initiation
- Survival percentage (%)
- Total root length (cm)
- Shoot length (cm)
- Root fresh weight (g)
- Shoot fresh weight (g)
- Root dry weight (g)
- Shoot dry weight (g)

Both datasets were subjected to analysis of variance (ANOVA) appropriate for a CRD. Mean separation was performed using LSD following a significant F-test at 5% level of significance. Statistical analysis was carried out using R software.

RESULTS AND DISCUSSION

Branch size exerted a significant influence on epicormic shoot initiation, growth, and rooting response, represented in (Table 1). The earliest sprouting was recorded in Treatment 1 (1.5 DAP), followed by Treatment 2 (3.33 DAP), whereas Treatments 3 and 4 showed progressively delayed sprouting, with Treatment 4 recording the maximum time to first sprout emergence (7.5 DAP). Smaller and juvenile branch cuttings exhibited earlier sprouting than larger, mature woody branches; however, shoot growth was more pronounced in larger branches, likely due to higher carbohydrate reserves [9]. Shooting percentage remained high across treatments, with Treatments 1, 2, and 4 recording 100%, 100%, and 91.67%, respectively, while Treatment 3 showed a comparatively lower shooting percentage of 75%. Despite the high shooting percentage in smaller branch classes, the number of shoots per branch increased significantly with branch size. Treatment 4 recorded the highest number of epicormic shoots per branch (18.33), followed by Treatment 3 (10.5), whereas Treatments 1 and 2 produced significantly fewer shoots. This trend suggests that larger branches possess a greater epicormic bud bank and higher stored carbohydrate reserves, which support the initiation of multiple shoots [10-11]. Similarly, in a study by Nascimento *et al.* [12] on epicormic shoot techniques in *I. paraguariensis* mother trees and its cutting, higher number of epicormic shoots were resulted from large branch cuttings.

Shoot growth parameters also showed a positive relationship with branch size with no significant difference in shoot diameter. Treatment 4 recorded the highest mean shoot length (22.5 cm) (Fig 2), followed by Treatment 3 (14.83 cm). In contrast, shoots produced from Treatments 1 and 2 were significantly shorter, reflecting limited reserve availability and reduced vascular support. These findings indicate that while small branches favour rapid sprouting, but they were unable to show vigourous shoot growth. Leaf production in the epicormic shoots varied significantly, with Treatment 3 recording the highest mean number of leaves per shoot (17.83), followed by Treatment 4 (14.5). Treatments 1 and 2 produced significantly fewer leaves, indicating poor shoot vigour. Higher leaf number in shoots derived from thicker branches enhances photosynthetic capacity, which is crucial for sustained shoot growth. Similar results were obtained by Gehlot *et al.* [13] in hardwood cuttings of *Azadirachta indica*, where large branch size resulted in better growth performance than the smaller branches.

The Shoot Vigour Index (SVI), which integrates shoot length, shoot diameter, and leaf number, clearly distinguished the treatments in terms of overall shoot quality. Treatments 3 and 4 recorded significantly higher SVI values (676.67 and 903.67, respectively), whereas Treatments 1 and 2 showed markedly lower vigour indices. The highest SVI observed in Treatment 4 highlights that thicker and longer branches produce a greater number of highly vigourous shoots.

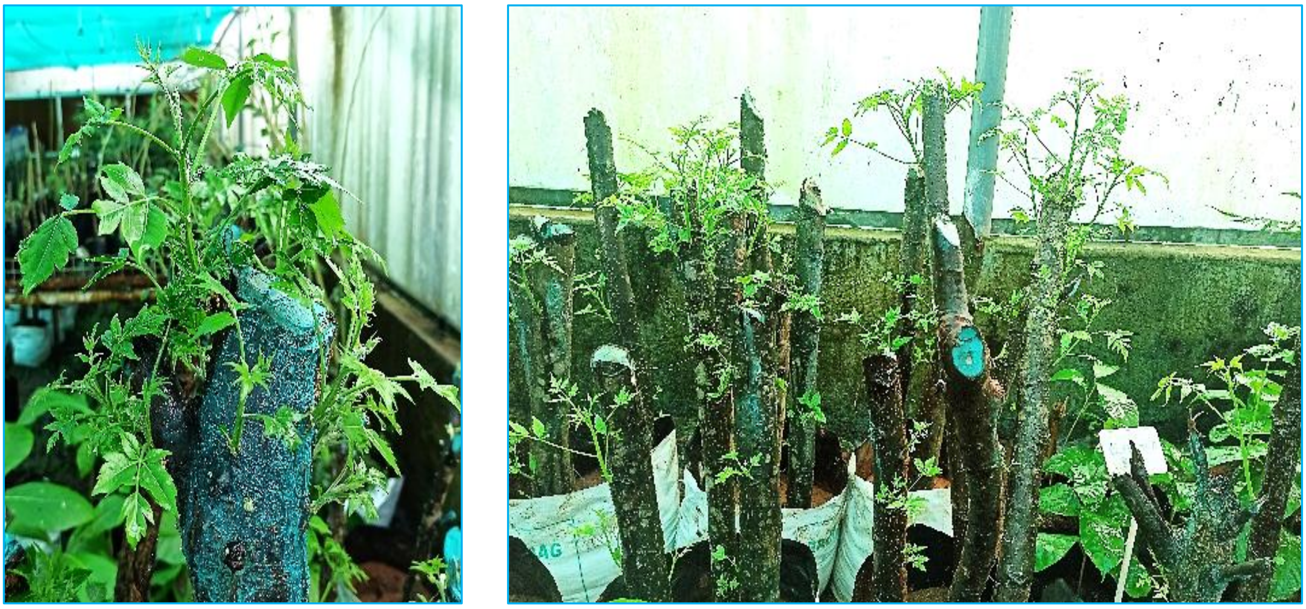

Fig 2 Epicormic shoots sprouted on branches

Rooting response and subsequent growth performance of epicormic shoots varied significantly among treatments, indicating a pronounced effect of branch size on propagation success (Table 2). Epicormic shoots derived from Treatments 1 and 2 failed to initiate roots, resulting in zero rooting and survival percentages. The absence of rooting in these treatments suggests that shoots originating from thinner branches lacked sufficient physiological maturity, carbohydrate reserves, endogenous auxin levels and structural development required for adventitious root initiation. In contrast, epicormic shoots from Treatments 3 and 4 exhibited successful rooting, with Treatment 4 recording a significantly higher rooting percentage (83.33%) compared to Treatment 3 (37.5%). Time taken for root initiation did not differ significantly between these two treatments, with roots emerging approximately 15-16 days after planting. Epicormic shoots were considered rooted when visible adventitious roots or root primordia emerged at the basal region (Fig 3). The higher rooting response observed in Treatment 4 can be attributed to the superior vigour of shoots derived from thicker and longer branches, which likely possessed enhanced endogenous hormonal balance and greater reserve availability, facilitating efficient root differentiation [14].

Fig 3 First day of root initiation on epicormic shoot

Survival percentage of rooted plantlets was 100% in both Treatments 3 and 4, indicating that once rooting was successfully established, the epicormic shoots were capable of sustaining growth under nursery conditions. However, significant differences were observed in root and shoot growth attributes. Treatment 4 recorded the highest total root length (94.5 cm) and shoot length (40.17 cm) (Fig 4b), followed by Treatment 3, which recorded 61.0 cm and 18.67 cm (Fig 4a), respectively. The enhanced root system in Treatment 4 reflects improved assimilate allocation and stronger vascular connectivity, supporting better shoot growth.

Fig 4 Rooted epicormic shoots under (a) Treatment 3 and (b) Treatment 4

Fresh and dry biomass accumulation further substantiated the superior performance of Treatment 4. Root fresh weight (0.85 g) and shoot fresh weight (5.13 g) were significantly higher in Treatment 4 compared to Treatment 3 (0.60 g and 2.6 g, respectively). Similarly, root dry weight and shoot dry weight were markedly greater in Treatment 4, indicating higher structural biomass accumulation. The comparatively lower biomass in Treatment 3 suggests moderate vigour, sufficient for rooting but limited in subsequent growth.

Table 1 Epicormic shoot parameters recorded on 50 days after planting the branches

Treatments	Days to first sprouting (DAP)	Shooting percentage	No. of shoots per branch	Mean shoot length (cm)	Mean shoot diameter (mm)	Mean number of leaves	Shoot vigour index
1	1.5^{d}	100^{a}	1.5^{d}	12.25^{b}	1.667	7.5^{c}	145.33^{b}
2	3.33^{c}	100^{a}	4.17^{c}	6.17^{c}	2.667	7.17^{c}	116.67^{b}
3	6^{b}	75^{b}	10.5^{b}	14.83^{b}	2.5	17.83^{a}	676.67^{a}
4	7.5^{a}	91.67^{a}	18.33^{a}	22.5^{a}	2.667	14.5^{b}	903.67^{a}

Table 2 Root and shoot parameters of epicormic shoot propagation recorded after four months of planting

Treatments	Rooting percentage	Time taken for rooting (DAP)	Survival percentage (%)	Total root length (cm)	Shoot length (cm)	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)
1	0^{c}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}
2	0^{c}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}
3	37.5^{b}	15.67^{a}	100^{a}	61^{b}	18.67^{b}	0.60^{b}	2.6^{b}	0.14^{b}	0.85^{b}
4	83.33^{a}	15.83^{a}	100^{a}	94.5^{a}	40.17^{a}	0.85^{a}	5.13^{a}	0.28^{a}	1.17^{a}

The superior epicormic shoot vigour and rooting success observed in larger branches can be explained through well-established anatomical and physiological mechanisms [15-16]. Increased branch diameter is associated with greater vascular continuity, higher cambial activity, and more developed xylem-phloem networks, which improve water transport and assimilate supply to emerging epicormic shoots [17-19]. Larger branches also possess higher pools of non-structural carbohydrates (NSCs), which serve as the primary energy source for shoot growth and adventitious root initiation [20]. Vigourous shoots supported by adequate reserves exhibit greater rooting competence due to improved endogenous auxin availability, stronger sink strength, and higher metabolic capacity to support root primordia formation [21-23]. In contrast, shoots arising from thinner branches, despite rapid bud break due to higher juvenility, are constrained by limited reserves and reduced vascular support, resulting in weak shoot development and failure of rooting [24].

CONCLUSION

This study establishes branch diameter as a key determinant of epicormic shoot quality and rooting success in *Melia dubia*. Although thinner branches produced earlier sprouting, the resulting shoots were weak and failed to root, indicating that rapid sprouting alone does not ensure successful propagation. In contrast, epicormic shoots derived from medium to larger branches exhibited greater vigour, successful rooting, and complete survival after transplanting, demonstrating a clear trade-off between early sprouting and propagation efficiency. Rooting percentages of up to 83.33% achieved under hormone-free conditions using larger branches were comparable to those reported with exogenous IBA application, highlighting the effectiveness of branch-size-based selection. Larger branches are therefore recommended as optimal source material for efficient, low-cost, and sustainable epicormic shoot-based clonal propagation of *M. dubia*. Future studies may focus on seasonal variation, anatomical and biochemical analyses, and field-level performance of epicormic shoot-derived plants to further strengthen and refine epicormic shoot-based propagation protocols for *Melia dubia*.

Conflict of interest

The authors declare that there is no conflict of interest.

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