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A PRELIMINARY EVALUATION OF YIELD PERFORMANCE AND PEELING CHARACTERISTICS OF CLONAL AND SEED-PROPAGATED CEYLON CINNAMON: *Cinnamomum verum* J.S. PRESL SYN. *Cinnamomum zeylanicum* BLUME OF SRI LANKA

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ABSTRACT

Cinnamomum verum, commonly known as true cinnamon, is an economically significant spice valued for its medicinal and commercial applications. Sri Lanka remains the primary producer of high-quality true cinnamon under the Ceylon cinnamon brand, but most of its plantations are aging and require replanting. This study investigates the effectiveness of seed-derived (SD) and vegetatively propagated (VP) cinnamon plants in terms of stem straightness, branching pattern, bark yield, and peeling efficiency. Data were collected from 30 plants each of SD and VP populations maintained under uniform conditions at the National Cinnamon Research and Training Centre (NCRTC), Thihagoda, Sri Lanka. The results revealed that, SD plants showed superior stem erectness, with 50% of stems being erect and 42% slightly curved, compared to 5% and 35%, respectively, in VP plants. In terms of peelability, 14% of SD plants exhibited high peelability and 58% good peelability, whereas VP plants recorded 0% and 30%, respectively. However, VP plants displayed significantly higher (P<0.05) bark yields (770.7 g per bush) than SD plants (693.5 g per bush) and larger average stem circumference. Although VP plants produced fewer total shoots, they had a higher shoot-to-harvestable shoot ratio, indicating improved yield efficiency. Morphological traits such as stem straightness and branching habit were strongly correlated with peeling efficiency, highlighting their importance in traditional processing. These findings highlight the trade-offs between propagation methods, suggesting that while SD plants offer superior peeling efficiency, VP plants provide better yield potential. The sustainability of VP methods requires further long-term study to assess their viability for large-scale replanting efforts. Future research should focus on optimizing VP techniques, improving plant uniformity, and promoting farmer education on sustainable propagation practices. This study provides essential insights for improving the efficiency of cinnamon propagation, ensuring consistent yields, and enhancing the overall quality of Ceylon cinnamon production in Sri Lanka.

Keywords: Cinnamomum verum, Ceylon cinnamon, Vegetative propagation, Seedling-derived plants, Bark-yield, Peeling-efficiency

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INTRODUCTION

Cinnamomum verum J.S. Presl Syn. *Cinnamomum zeylanicum* Blume commonly known as Ceylon cinnamon or true cinnamon, is a highly valued spice due to its distinct flavor, aroma, and wide array of medicinal and pharmacological properties (Nabavi et al., 2015; Rao and Gan, 2014; Vangalapati et al., 2012; Ravindran et al., 2004). As one of the most economically significant spices in the global market, *C. verum* has been traditionally cultivated in Sri Lanka, which remains the leading exporter of high-quality cinnamon (Suriyagoda et al., 2021). The demand for Ceylon cinnamon has surged in recent years, driven by its health benefits, including anti-inflammatory, antioxidant, antimicrobial, and potential antidiabetic effects (Suriyagoda et al., 2021; Liyanage et al., 2021a; Bandusekara et al., 2025). Despite its economic importance, challenges persist in ensuring the sustainability and uniformity of cinnamon production, particularly in terms of maintaining high-quality planting material and improving productivity through efficient propagation methods.

In Sri Lanka, most cinnamon plantations are old and require replanting in the near future to maintain production levels and meet increasing global demand. Understanding the limitations of different propagation methods is crucial for ensuring the success of replanting efforts. While seed propagation is widely practiced, its limitations in maintaining genetic uniformity and productivity raise concerns about its long-term effectiveness. If vegetative propagation is to be promoted as an alternative, it is essential to evaluate its sustainability and long-term applicability. Research on the comparative efficiency of propagation methods will provide valuable insights for optimizing replanting strategies, improving yield, and enhancing the overall quality of Ceylon cinnamon production.

The success of commercial cinnamon cultivation largely depends on propagation techniques, as they influence the genetic uniformity, growth rate, yield potential, and quality of the final product. Cinnamon is primarily propagated through seeds and vegetative propagation (VP) methods, each having its own advantages and drawbacks (Paul and Sahoo, 1993). While seed propagation is widely practiced due to its simplicity and cost-effectiveness, it presents a major challenge in maintaining uniformity among cultivated plants. This is because *C. verum* is a cross-pollinated species, leading to significant genetic variability among seedlings (Liyanage et al, 2021b). Such variability can affect key agronomic traits, including bark thickness, peeling ability, and essential oil composition, ultimately impacting the commercial value of cinnamon (Liyanage et al., 2021b).

Vegetative propagation, on the other hand, ensures the production of genetically identical offspring to the parental plant, thereby maintaining uniformity in plantations. Various VP methods, such as stem cuttings, air layering, and tissue culture, have been explored to enhance propagation efficiency in cinnamon (Rema et al., 1997). Stem cuttings and air layering are commonly used techniques that facilitate the establishment of true-to-type planting material. However, these methods have limitations, including low rooting success, high mortality rates in the field, and labor-intensive management. Tissue culture techniques, although promising, are still underutilized due to high initial costs, low rooting success and high mortality rates in the field. Consequently, many cinnamon growers continue to rely on seed propagation despite its inherent variability, largely due to ease of management and lower input costs.

The establishment of homogeneous plantations is critical for maintaining consistent yield and quality in cinnamon production. The genetic heterogeneity observed in seedling-derived populations can lead to variations in growth rates, bark yield, and peeling efficiency, which are crucial factors for commercial processing (Liyanage et al., 2021b). However, no comprehensive local studies have been conducted to comparatively assess plant uniformity in growth parameters and yield characteristics between vegetatively propagated (VP) and seedling-derived cinnamon plants. Furthermore, uniformity in morphological and physiological traits plays a critical role in improving processing efficiency, minimizing post-harvest losses, and enhancing overall market value.

Despite the advancements in propagation techniques, the adoption of vegetative propagation in commercial cinnamon plantations remains limited. Factors such as the availability of high-quality mother plants, labor costs, and knowledge gaps among farmers contribute to the slow transition from seed-based to vegetative propagation systems. Additionally, there is a need for further research to optimize VP techniques for large-scale implementation and to develop cost-effective methods that encourage wider adoption among cinnamon growers.

This study aims to address key issues related to cinnamon propagation methods and propose potential solutions to enhance the efficiency and sustainability of cinnamon cultivation. The research was conducted at the National Cinnamon Research and Training Centre (NCRTC), *Thihagoda*, Sri Lanka, using seedling and VP populations of *C. verum* maintained under the same management conditions. The study focused on evaluating bark yield, peeling ability, and five morphological characteristics influencing traditional processing efficiency. By comparing the performance of seedling-derived and vegetatively propagated plants, this study seeks to provide insights into the most effective propagation strategies for improving cinnamon productivity and quality. The findings of this research will be valuable for policymakers, researchers, and cinnamon growers in developing best practices for sustainable cinnamon cultivation.

METHODOLOGY

Sample Collection

Data were collected from both SD and VP populations established at the National Cinnamon Research and Training Centre (NCRTC). Altogether 30 plants were examined from each VP and SD populations.

Screening for morphological characters

Based on visual observations, the stem straightness was categorized into five different classes (Figure 1 A), as almost straight stem scored as one, slightly curved stems scored as two, stems with irregular bends scored as three and stems with irregular bends and knots scored as four. The maximum branching, present along the stems was measured at different three levels. First, one-meter height from the ground level considered as bottom part, one-meter to two-meter height was considered as middle part and above two-meter considered as top part (Figure 1 B). The total number of shoots and harvestable shoots were counted per bush. Stem circumference and height was recorded from the most matured harvestable stems. Stem circumference was measured at three different levels as 0.5 m, 0.75 m and 1 m height from the ground level. All the measurements were taken according to the cinnamon descriptor TURES 2013 project, 2016.

Screening on yield and peel ability

All matured harvestable stems were collected from SD and VP plants and peeled according to the traditional processing system. Fresh weight was recorded (g) along with the peeling ability. Peelability was recorded based on a developed scoring scale as, Low peelability-2, Normal peelability-5, Good peelability- 8 and High peelability- 10.

Statistical analysis

Descriptive statistics, including percentages, were calculated for qualitative traits such as stem straightness, branching habit, and peelability. For quantitative traits, a two-sample t-test was performed to compare the means between SD and VP populations. All statistical analyses were conducted using Minitab version 19, with a significance level set at $p < 0.05$.

RESULTS AND DISCUSSION

The results revealed significant differences in qualitative characteristics, peeling efficiency, and bark yield between SD and VP plants of *C. verum.* SD plants exhibited superior stem erectness, with over 50% of stems being erect and 40% slightly curved (Figure 2). In contrast, VP plants demonstrated higher stem irregularity, with 50% of stems showing bends and 30% being slightly curved (Figure 2). These differences directly impacted peeling efficiency, as more erect stems with fewer branches enhance the peeling quality of cinnamon.

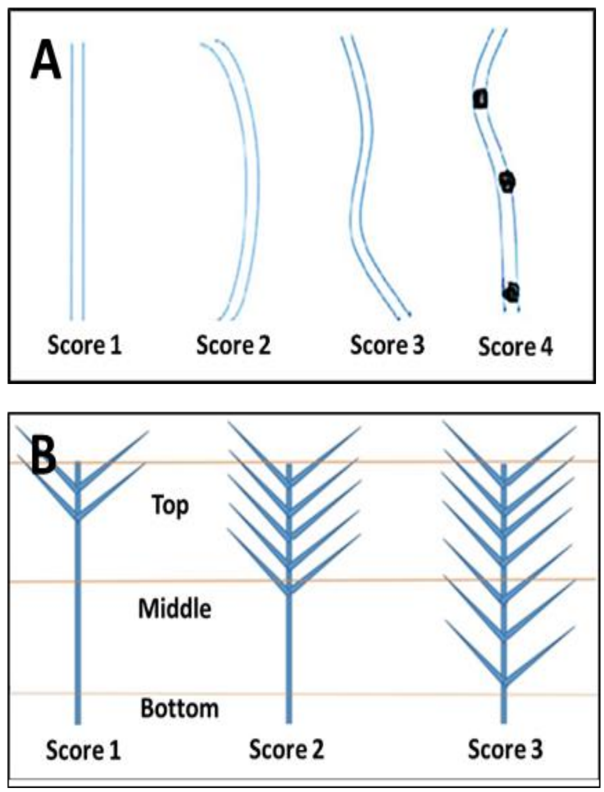

Figure 1: Scoring for straightness (A) and branching habit (B)

Notes: (A) Scoring for straightness; Score 1 - Erect stems, Score 2 – Slightly curved stems, Score 3 – Stems with irregular bends, Score 4 – Stems with bends and knots. (B) Branching habit; Score 1 – Branching at the top level (> 2m), Score 2 – Branching up to the middle of the stem (1-2 m), Score 3 – Branching up to the bottom of the stem

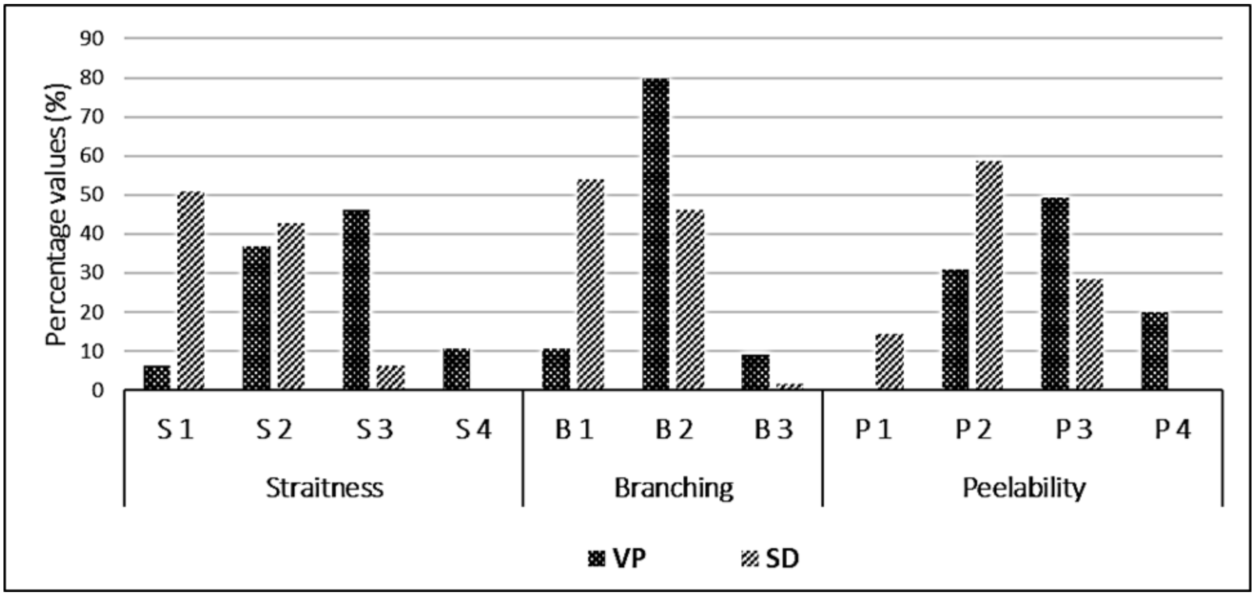

Figure 02. Descriptive statistics of qualitative traits and peelability of VP and SD plants of *C. verum*

***Notes:** Scoring for straighiness; S1 - Erect stems, S2 – Slightly curved stems, S3 – Stems with irregular bends, S4 – Stems with bends and knots. Branching habit; B1 – Branching at the top level (> 2 m), B2 – Branching up to the middle of the stem (1-2 m), B3 – Branching up to the bottom of the stem., Peel ability; P1 - High peel ability P2 - Good peel ability, P3 - Normal peel ability, P4 - Low peel ability.*

Peeling ability was significantly higher in SD plants, with over 70% of sticks exhibiting good peelability compared to only 30% in VP plants (Figure 2). Most VP plants demonstrated normal peeling performance, indicating that their stem structure is less favorable for efficient peeling. Previous studies have shown that planting spacing (Aluthgamage et al., 2021) and urea application intervals (Kaushalya et al., 2024) influence cinnamon peelability. The present findings suggest that, in addition to these factors, morphological traits such as stem straightness and branching pattern also play a key role in processing efficiency.

Quantitative trait analysis further highlighted significant differences between SD and VP plants. VP plants had a significantly higher average bark yield (770.7 g per bush) compared to SD plants (693.5 g per bush) (Table 1). VP plants also exhibited a larger average stem circumference (14.3 cm vs. 10.1 cm in SD plants) and a higher total shoot-to-harvestable shoot ratio (0.6 vs. 0.4 in SD plants) (Table 1).

However, SD plants maintained a higher number of total shoots (7.4 vs. 3.6 in VP plants), indicating a trade-off between shoot number and bark yield. This suggests that reducing unnecessary shoots at an early stage could enhance overall yield. Moreover, the significantly highest harvestable shoots were reported from SD (1.9) as it showed 1.1 for VP.

The correlation analysis among morphological and yield-related traits provides insight into the relationships that influence cinnamon productivity. Canopy spread and total shoots showed a strong positive correlation ($r = 0.897$) ($P<0.05$), indicating that trees with wider canopies tend to develop a higher number of total shoots. This may be attributed to better light interception and nutrient allocation that support multiple shoot development. A strong negative correlation was observed between total shoot number and bark yield ($r = -0.917$) ($P=0.00$), suggesting that trees with excessive vegetative growth tend to allocate fewer resources toward bark thickening, ultimately reducing yield. Harvestable shoot number also showed a negative correlation with total shoots ($r = -0.882$) ($P=0.00$), reinforcing the idea that increased shoot production does not necessarily translate into a higher number of marketable shoots. Stem circumference had a moderate positive correlation with bark yield per bush (r = 0.569) (P=0.15), implying that thicker stems tend to yield more bark. This suggests that selection for larger stem diameter may be beneficial for enhancing bark production. The correlation between stem circumference and total shoot number (r = 0.669) (P=0.09) was also positive, indicating that plants with larger stems generally support more shoots. However, this does not directly translate to a higher number of harvestable shoots, as seen from the negative correlation between stem circumference and harvestable shoot number (r = -0.713) (P=0.07).

Table 1. Descriptive statistics of quantitative traits of VP and SD plants of *C. verum*

Characters	SD	VP	Percentage difference in VP compared to SD
Average stem circumference (cm)*	10.1± 1.5	14.3 ± 1.6	+ 41.58 %
Average canopy spread (cm)*	147.3 ± 8.5	167.4 ± 10.5	+ 13.64 %
Average number of total shoots*	7.4 ± 2.6	3.6 ± 1.3	- 51.35 %
Average number of harvestable shoots*	1.9 ± 0.2	1.1 ± 0.1	- 42.10 %
Harvestable shoot/Total shoot*	0.4± 0.08	0.6 ± 0.06	+ 50.00 %
Average bark yield per bush (g)*	693.5 ± 28.5	770.7 ± 38.5	+ 11.13 %

Notes*; Value are with a mean of total 30 replicates per each. Bark yield was taken as wet weight. Results were presented as mean ± standard deviation (SD). Significantly different characters were expressed as "*". The significant level is (P<0.05).*

Table 2. Correlation Analysis of Morphological and Yield-Related Traits in Cinnamon Populations

	ASC	ACS	ANTS	ANHS	ABYB	S	BH	P
Average stem circumference (ASC)	1							
Average canopy spread (ACS)	0.58	1						
Average number of total shoots (ANTS)	0.66	0.89*	1					
Average number of harvestable shoots (ANHS)	-0.71	0.57	-0.88*	1				
Average bark yield per bush (ABYB)	0.56	-0.88*	-0.91*	-0.59	1			
Straightness (S)	-0.14	-0.73	0.62	0.32	0.58	1		
Branching habit (BH)	-0.03	-0.70	0.66	0.25	0.57	0.85*	1	
Peelability (P)	0.04	-0.65	0.52	0.37	0.42	0.87*	0.74	1

Peelability showed a strong positive correlation with stem straightness (r = 0.876) (P=0.00) and branching habit (r = 0.742) (P=0.08). This suggests that trees with straighter stems and well-organized branching structures exhibit better peeling efficiency. These traits are crucial for commercial cinnamon processing, as easier peeling reduces labor costs and processing time. Straightness and branching habit were also positively correlated (r = 0.859), indicating that trees with straight stems tend to have a more structured branching pattern, which contributes to ease of harvesting and processing. Branching habit had a moderate positive correlation with bark yield per bush (r = 0.573) (P=0.15), suggesting that trees with optimal branching structures may contribute to better yield. This could be due to efficient resource allocation that supports bark thickening. A moderate positive correlation was observed between straightness and bark yield (r = 0.583) (P=0.14), indicating that straighter stems may facilitate improved bark quality and higher yields.

The correlation results highlight several key factors that influence cinnamon productivity. Canopy spread and total shoot number showed a strong positive relationship, but excessive shoot production appeared to reduce harvestable shoot count and bark yield, suggesting that proper pruning or thinning strategies may be required to optimize productivity. The strong correlation between stem straightness, branching habit, and peelability underscores the importance of selecting trees with structurally sound characteristics for easier processing. Additionally, the positive correlation between stem circumference and bark yield suggests that breeding programs should prioritize thicker stems for maximizing cinnamon bark production. Overall, these findings provide valuable insights for plant selection, breeding, and management strategies aimed at improving cinnamon productivity and quality. Future studies could incorporate genetic and environmental factors to refine selection criteria for high-yielding and easily processable cinnamon plants.

This study highlights the distinct agronomic and processing-related advantages of seedling-derived (SD) and vegetatively propagated (VP) *Cinnamomum verum* plants. SD plants exhibited superior stem straightness and peelability, making them favorable for traditional processing and field resilience. Conversely, VP plants demonstrated higher bark yield and morphological uniformity, which are critical for achieving commercial productivity and consistency. These findings suggest that an integrated approach—strategically combining both propagation methods—may offer an optimal balance between yield and processing efficiency in cinnamon cultivation.

To further bridge this gap, embryo culture presents a promising propagation alternative. Embryo-cultured plants naturally develop a taproot system, unlike VP plants, enhancing field establishment, drought tolerance, and long-term stability (George et al., 2008). Moreover, embryo culture enables the propagation of genetically uniform plants, and when combined with molecular marker-assisted selection, it holds potential for developing elite cinnamon lines that combine the yield advantages of VP with the processing benefits and field vigor of SD plants. Despite these advantages, large-scale adoption of embryo culture in cinnamon remains limited, primarily due to the need for specialized laboratory facilities, skilled personnel, and relatively higher production costs compared to conventional propagation. In Sri Lanka, research on molecular marker-assisted selection in cinnamon is still in its early stages, though preliminary work using RAPD, ISSR, and SSR markers has demonstrated its feasibility for genetic diversity assessment and trait selection (Jayasinghe et al., 2021; Ranasinghe et al., 2020), indicating potential for integration with embryo culture in future breeding programs.

To enhance cinnamon productivity and quality, future research should prioritize refining VP and embryo culture techniques while integrating sustainable agronomic practices such as optimized pruning, shoot regulation, and nutrient management. However, a key limitation of this study is its short-term scope. Long-term, multi-seasonal assessments are essential to fully understand the performance, stability, and adaptability of different propagation methods. In addition, environmental variables such as soil characteristics and climatic conditions should be incorporated into future studies to evaluate genotype-by-environment interactions more effectively.

To improve the adoption of improved propagation methods, particularly VP and embryo culture, it is essential to implement training programs, awareness campaigns, and financial incentives for growers. The development and dissemination of cost-effective propagation technologies will play a vital role in ensuring the widespread, sustainable production of high-quality cinnamon in Sri Lanka and beyond.

CONCLUSION

In conclusion, this study underscores the critical influence of propagation methods on the morphological characteristics, bark yield, and peeling efficiency of *Cinnamomum verum*. Seedling-derived (SD) plants exhibited superior stem straightness and peelability, traits that are essential for traditional processing and field adaptability. In contrast, vegetatively propagated (VP) plants showed significantly higher bark yields and improved productivity, indicating their potential for commercial-scale cultivation. To enhance the sustainability and efficiency of cinnamon production, further research should focus on optimizing vegetative propagation protocols and exploring advanced techniques such as embryo culture. The integration of targeted agronomic practices and farmer capacity-building initiatives will be essential to support the widespread adoption of improved propagation systems. These efforts will contribute to a consistent and high-quality supply of Ceylon cinnamon, strengthening its competitiveness in the global market.

Conflict of interest

The authors declare that they have no competing interests.

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