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RESEARCH ARTICLE

QUANTITATIVE AND QUALITATIVE ASPECTS OF CINNAMON (*Cinnamomum verum* J. Presl) BARK YIELD UNDER MODIFIED PLANTING SYSTEMS

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Abstract

Cinnamon is one of the most important export crops in Sri Lanka, which generates a considerable amount of foreign exchange for the country. Therefore, special emphasis should be given to enhancing its production as well as quality. Hence, the study was conducted to evaluate some important quantitative and qualitative aspects of the cinnamon yield, namely, cumulative bark yield, bark dry matter percentage, biological yield, the composition of the biological yield and organoleptic properties under some modified planting systems. Seedlings and vegetatively propagated plants of cinnamon variety Sri Gemunu were planted under three different spatial patterns 1.2×0.6 m with three plants per hill, 1.2×0.4 m with two plants per hill and 1.2×0.2 m with one plant per hill while maintaining equal planting density in a unit area. Plants were harvested according to two harvesting intervals, 6 and 8 months and required measurements were taken. According to the results, the effect of harvesting interval and the interaction effect between planting material and the spatial pattern was significant ($p < 0.05$) for the cumulative cinnamon bark yield for two years (kg/ha). However, tested factors were not significant ($p < 0.05$) for the bark dry matter percentage. In contrast, the effects of harvesting interval and planting materials were significant ($p < 0.05$) for the biological yield of cinnamon plants. When considering the composition of the above-ground biological yield of cinnamon plants, the interaction effect between planting material and the spatial pattern was significant ($p < 0.05$) for the percentages of all components (bark, leaves, stem wood, scrape, immature stems and the un-peelable portion of the mature stems and branches). Vegetatively propagated plants consist of a higher bark oil content and a cinnamaldehyde percentage than seedlings. In contrast, seedlings consist of higher eugenol and cinnamyl acetate percentage than vegetatively propagated plants. When considering benzyl benzoate, β-linalool and β-caryophyllene, an impact from the tested factors was not observed.

Keywords: Bark yield, Biological Yield, Cinnamon, Dry Matter Percentage, Organoleptic Properties, Productivity

INTRODUCTION

Being an island with rich biodiversity, Sri Lanka contributes largely to the global market through a vast collection of plant-based products. Among them, Ceylon cinnamon (*Cinnamomum verum* J. Presl), the dried bark of cinnamon plants obtained through a laborious process, claims a higher position over centuries. Though cinnamon is mainly recognized as a spice, it is a multifaceted plant with numerous uses (Suriyagoda *et al*. 2021). Cinnamon is considered the fourth export agricultural crop and plays a vital role in the Sri Lankan economy (De Silva and Esham 2020). Export earnings obtained through cinnamon-based products for 2020 have been recorded as 216.4 million US dollars (Workman 2021). Therefore, particular emphasis should be given to the quantity and quality of produced cinnamon bark to maintain the current market and expand it.

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Crop productivity is the quantitative measure of crop yield in a given measured area of the field. Currently, the average productivity of cinnamon plantations in Sri Lanka is around 500 kg/ha despite the potential of 1500 kg/ha in the case of cinnamon bark yield (Jayasinghe *et al*. 2018). Hence, there is an urgent need to enhance the productivity of cinnamon lands to reduce the gap between current production and potential value, which will be a considerable advantage to export earnings.

As cinnamon bark is exported as a dried product, the dry matter percentage plays an essential role in determining the final yield. During the cinnamon processing procedure, the moisture content of the bark is reduced by up to 10% (Dayananda *et al*. 2003). Therefore, the knowledge of the impact of various factors on the bark dry matter percentage of cinnamon is important to provide more favourable conditions to enhance productivity.

The biological yield of a plant consists of all prevailing plant parts, while the relative contribution of the economically valuable plant part can be varied based on several reasons. Though a considerable portion of biological yield consists of non-economical plant parts, as they are essential for the production of the economically important plant part, the relative contribution of those plant parts to the biological yield is equally important (Brouwer 1962). A better understanding of the relative contribution of each plant part to the biological yield and factors affecting the relative contribution may help gain the maximum benefits of a plant while increasing the economical yield to the optimum level. In the case of cinnamon, the bark is considered as the economical yield, while biological yield consists of bark, leaves, stem wood, scrape, immature stems and the un-peelable portions of the mature stems, branches and the bellow ground portion, which consists of the root mass. As a crop with a continuous coppicing system, determining the biological yield and its composition compared to the above-ground portion is the most practical procedure.

Cinnamon bark consists of numerous secondary metabolites, which determine its organoleptic properties. The strength of organoleptic properties increased with the oil content of the bark. Cinnamaldehyde, eugenol, cinnamyl acetate, benzyl benzoate, β -linalool and β-caryophyllene can be identified as important secondary metabolites regarding the cinnamon bark quality (Liyanage *et al*. 2017; Paranagama *et al*. 2020). As the composition of those secondary metabolites is a major determinant of the quality of the final product, knowledge of the factors affecting them is crucial to enhance the quality.

Hence, the study was conducted to evaluate some important quantitative and qualitative aspects of the cinnamon bark yield under some modified planting systems, namely, cumulative bark yield, bark dry matter percentage, biological yield, the composition of the biological yield, bark oil content and its composition.

MATERIALS AND METHODS

The study was conducted in a research field at the Faculty of Agriculture, University of Ruhuna, Sri Lanka, which belongs to the low county wet zone (WL_2) with annual average rainfall above 2,500 mm. The study was conducted from 2016 to 2020.

Uniformly grown healthy seedlings and vegetatively propagated plants (rooted cuttings) of the cinnamon variety Sri Gemunu were used as planting materials for the study.

Field establishment

After the initial land preparation, 2.4×3.0 m plots were prepared. Plants were established according to three spatial patterns 1.2×0.6 m with three plants per hill (A), 1.2×0.4 m with two plants per hill (B) and 1.2×0.2 m with one plant per hill (C). There were three plant rows in each plot, and the middle plants of the middle row were used for the data collection to prevent the border effect. The plant density was equal (41,666 plants/ha) for all treatment combinations.

Data collection and analysis

The first harvest was collected after two years from the field establishment. Afterwards, harvesting proceeded according to two harvesting intervals, six months and eight months. As stems were not up to the harvestable maturity level at the time, the harvesting interval was doubled for the second harvest. The field was maintained according to the recommendations of the Department of Export Agriculture, Sri Lanka, throughout the study.

For each harvest, cinnamon quills were prepared with the support of a skilled cinnamon peeler and weights were recorded after air drying for three days. Bark samples were collected during the bark processing procedure and oven dried to a constant weight at 105 ˚C. Both the fresh weight and dry weight of the samples were recorded. Cumulative bark yield per hectare was calculated for two years, and bark dry matter percentages were calculated for the second and third harvests with collected data.

The biological yield of cinnamon plants under each treatment condition and the organoleptic properties of the bark were measured two years after the first harvest. Plants were removed above ground level, and samples of separate plant parts (bark, leaves, stem wood, scrape, immature stems and the un-peelable portions of the mature stems and branches) were oven dried at 105 ˚C to a constant weight. Above ground biological yield of cinnamon plants and the percentage dry weight of each plant part compared to the total plant dry weight was calculated to identify the composition of biological yield. Bark oil content and its composition were analyzed through the GC-MS (Gas Chromatography-Mass Spectrometry) procedure.

The experiment was conducted according to a three-factor factorial (three spatial patterns, two planting material types and two harvesting intervals) split plot design with four replications. The collected data were statistically analyzed using appropriate statistical techniques.

RESULTS AND DISCUSSION

According to the results, the interaction effect between planting material and the spatial pattern was significant ($p < 0.05$) for cumulative cinnamon bark yield for two years. The highest bark yield (2900.2 kg/ha) was recorded in the seedlings established under spatial pattern C. The lowest bark yield (1448.7 kg/ha) was recorded in the vegetatively propagated plants established under spatial pattern C. The value was not significantly different ($p < 0.05$) from the bark yield of vegetatively propagated plants established under spatial pattern B (1614.7 kg/ha) (Figure 1 (A)). Simultaneously, the effect of harvesting interval was significant ($p < 0.05$) for cumulative cinnamon bark yield for two years. The harvest was significantly higher ($p < 0.05$) when harvested in 6 months intervals (2233.9 kg/ha) than when harvested

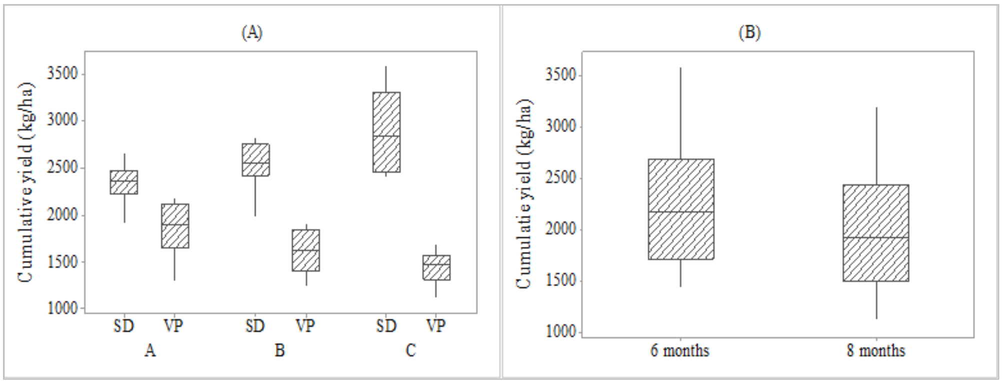

Figure 1 (A): Cumulative cinnamon bark yield for two years as affected by planting material and spatial pattern (SD: Seedlings; VP: Vegetatively propagated plants; A: 1.2×0.6, 3 plants/hill; B: 1.2×0.4, 2 plants/hill, C: 1.2×0.2, 1 plant/hill); (B): Cumulative cinnamon bark yield for two years as affected by the harvesting interval

in 8 months intervals (1993.9 kg/ha) (Figure 1 (B).

Being a crop with a unique harvestable portion, three yield indices have been identified for cinnamon, i.e. the number of harvestable stems per plant, harvestable length of a stem and unit bark weight, which determines its final yield (Pathiratna 2007). A study by Aluthgamage *et al*. 2021 revealed that the effect of planting material and spatial pattern (either as an interaction effect or the main factor effect) was significant for all three yield indices of cinnamon. Current findings also prove that, while maintaining an equal plant density, seedlings tend to produce a higher bark yield under closer spacing with fewer plants per planting hole. In comparison, vegetatively propagated plants tend to produce a higher bark yield under wider spacing with a higher number of plants per planting hole.

Though eight months harvesting interval provides more time to produce bark, the number of harvests is higher within two years when harvested in six months harvesting interval. Hence, considering cumulative harvest for two years, harvesting in six months intervals proved more beneficial.

The spatial pattern of a crop establishment determines the mutual shading at the individual level. Cinnamon, a sun-loving tropical evergreen tree crop, is greatly affected by mutual shading. According to Pathiratna and Perera 2006 cinnamon plants tend to produce longer and erect stems under optimum mutual shading levels, which enhances the final bark yield. Changes occurred in light quantity and quality due to mutual shading affect the dry matter production and distribution of the plant as well (Pathiratna 2007). Hence, the bark dry matter percentages were tested under some modified planting systems.

The results revealed that interaction effects or main effects were not significant ($p < 0.05$) for the bark dry matter percentage during second harvest as well as third harvest. The average bark dry matter percentage during the second and third harvests was 35.33% and 37.16%, respectively (Figure 2).

Since the modified planting systems did not affect the cinnamon bark dry matter percentage, the above-ground biological yield was tested for an effect. According to the results, interaction effects were not significant ($p < 0.05$) on the above-ground biological

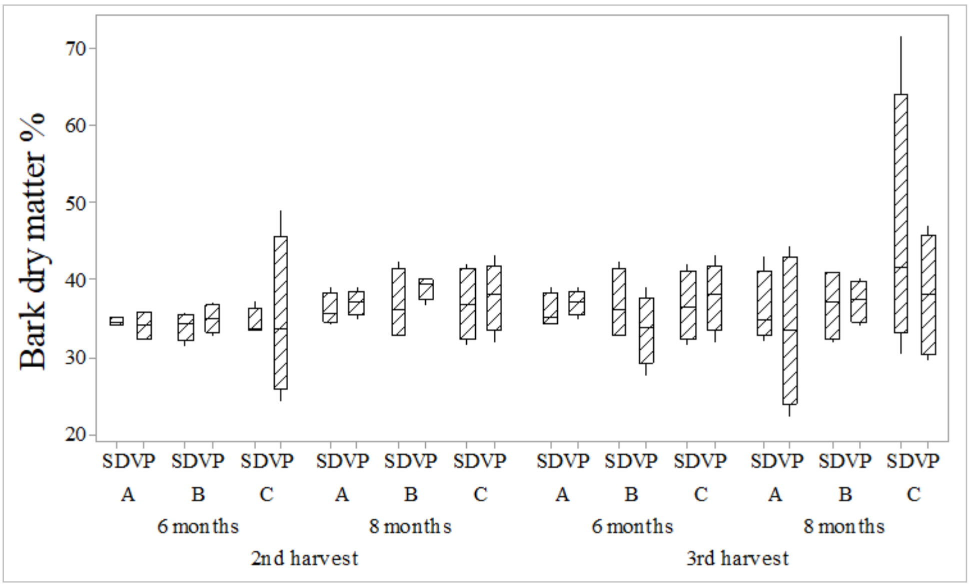

Figure 2: Bark dry matter percentage of cinnamon during 2nd harvest and 3rd harvest (SD: Seedlings; VP: Vegetatively propagated plants; A: 1.2×0.6, 3 plants/hill; B: 1.2×0.4, 2 plants/ hill, C: 1.2×0.2, 1 plant/hill; 6 months: 6 months harvesting interval; 8 months: 8 months harvesting interval)

yield of cinnamon plants. In contrast, the effect of harvesting interval and planting material were significant ($p < 0.05$). The biological yield of cinnamon plants harvested in eight months harvesting intervals (1334.5 g) was significantly higher ($p < 0.05$) than the cinnamon plants harvested in six months harvesting intervals (1030.9 g) (Figure 3 (A)). Simultaneously, the biological yield of seedlings (1374.0 g) was significantly higher than the vegetatively propagated plants (991.3 g) (Figure 3 (B)).

Plants have a longer period to accumulate dry matter when harvested in longer intervals. Hence, the biological yield of cinnamon plants harvested in eight months was higher than those harvested in six months harvesting intervals. At the same time, vegetatively propagated plants undergo an inherent disadvantage due to the lack of shoot and root apical meristems, which consist of higher auxin concentrations (Leyser, 2010) which have a dominant role in plant elongation. Therefore, vegetatively propagated plants develop a rather bushy and stout structure, causing a comparatively lower biological yield than seedlings.

Similar to the biological yield, knowledge of its composition is also crucial for the enhancement of the productivity of cinnamon plants. Hence, the impact of spatial pattern, harvesting interval and planting material were tested on the percentages of different above-ground plant parts (bark, leaves, stem wood, scrape, immature stems and the un-peelable portion of the mature stems and branches) compared to the above-ground biological yield. According to the results, the interaction effect between planting material and the spatial pattern was significant ($p < 0.05$) for all causes.

The highest bark percentage was recorded in the seedlings established under spatial pattern C (5.41%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern A (4.50%) and seedlings established under spatial pattern B (4.27%). Simultaneously, the lowest bark percentage was recorded in the vegetatively propagated plants established under spatial pattern C (3.07%). The value was not significantly different ($p < 0.05$) from the seedlings established under spatial pattern A (3.53%) and vegetatively propagated plants established under spatial pattern B (3.66%) (Figure 4 (A)).

Seedlings established under the spatial pattern C had a significantly higher ($p < 0.05$) cumulative bark yield than all other treatments. Similarly, vegetatively propagated plants established under the spatial pattern A had a significantly higher ($p < 0.05$) cumulative bark yield than the other two treatments consisting of vegetatively propagated plants. Allocation of a comparatively higher percentage of dry matter to the bark can be a reason for that outcome.

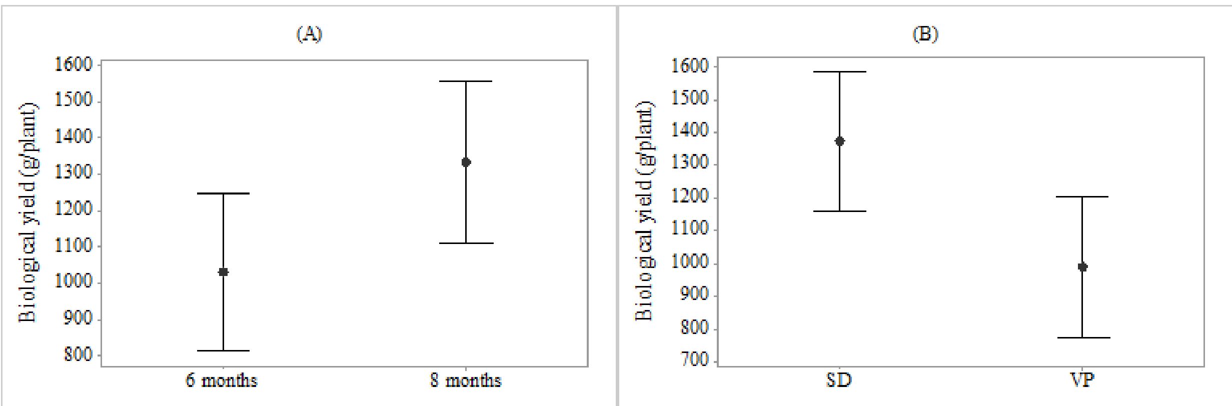

Figure 3 (A): Biological yield of cinnamon plants as affected by the harvesting interval; (B): Biological yield of cinnamon plants as affected by the planting material (SD: seedlings; VP: vegetatively propagated plants)

The highest leaf percentage was recorded in the vegetatively propagated plants established under spatial pattern A (33.91%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern B (32.75%) and seedlings established under spatial pattern C (31.36%). The lowest leaf percentage was recorded in the seedlings established under spatial pattern B (26.07%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern C (28.92%) (Figure 4 (B)).

Leaves are the primary sites of photosynthesis. Therefore, having a significantly higher proportion of leaves is beneficial for the productivity of the crop. In the case of seedlings established under the spatial pattern C, it appeared to be rather beneficial, having a comparatively higher percentage of dry matter allocated to the bark and leaves.

The highest stem percentage was recorded in the seedlings established under spatial pattern C (34.70%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern A (32.27%) and seedlings established under spatial pattern B (31.38%). The lowest

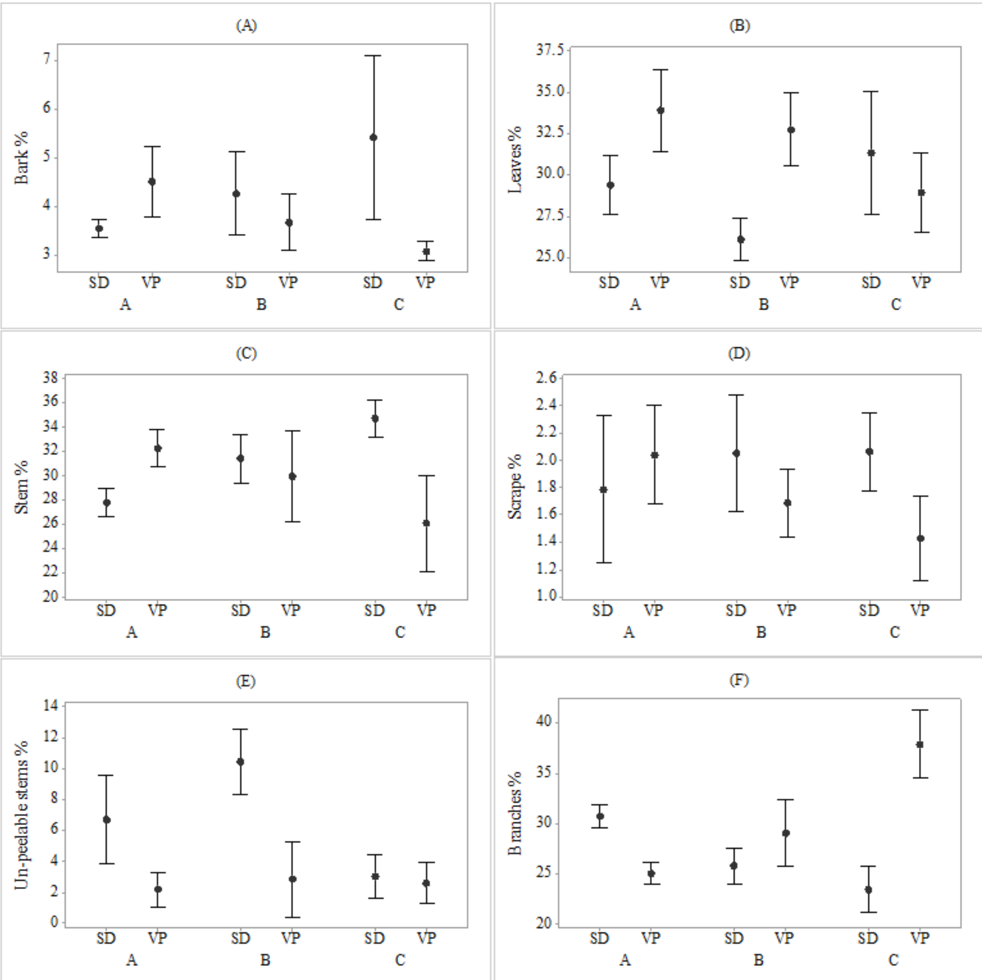

Figure 4: Composition of the above-ground biological yield of cinnamon plants after four years from the field establishment as affected by the interaction effect between spatial pattern and planting material. (A): Bark, (B): Leaves, (C): Stems, (D): Scrape, (E): Immature stems and the un-peelable portions of the mature stems, (F): Branches (SD: Seedlings; VP: Vegetatively propagated plants; A: 1.2×0.6, 3 plants/hill; B: 1.2×0.4, 2 plants/hill, C: 1.2×0.2, 1 plant/hill)

stem percentage was recorded in the vegetatively propagated plants established under spatial pattern C (26.07%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern B (29.97%) and seedlings established under spatial pattern A (27.80%) (Figure 4 (C)).

According to the results, the bark yield increased with the amount of dry matter allocated to stem wood. The reason can be the increment of the surface on which the bark is produced with the increased production of stems.

The highest scrape percentage was recorded in the seedlings established under spatial pattern C (2.06%), which was significantly different ($p < 0.05$) only from the lowest value. The lowest scrape percentage was recorded in the vegetatively propagated plants established under spatial pattern C (1.43%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern B (1.69%) and seedlings established under spatial pattern A (1.79%) (Figure 4 (D)).

The highest percentage of immature stems and the un-peelable portions of the mature stems were recorded in the seedlings established under spatial pattern B (10.46%), which was significantly different ($p < 0.05$) from all other values. The lowest percentage was recorded in the vegetatively propagated plants established under spatial pattern A (2.19%). The value was not significantly different ($p < 0.05$) from the vegetatively propagated plants established under spatial pattern B (2.85%) and C (2.59%), as well as seedlings established under spatial pattern C (3.03%) (Figure 4 (E)).

The highest percentage of branches was recorded in the vegetatively propagated plants established under spatial pattern C (37.92%), which was significantly different ($p < 0.05$) from all other values. The lowest percentage was recorded in the seedlings established under spatial pattern C (23.44%). The value was not significantly different ($p < 0.05$) from the seedlings established under spatial pattern B (25.77%) and vegetatively propagated plants established under spatial pattern A (25.09%) (Figure 4 (F)).

According to the results, the lowest cumulative yield was recorded in the vegetatively propagated plants established under the spatial pattern C. Allocation of a higher amount of dry matter for the production of branches can be a reason for this condition.

Though vegetatively propagated plants were at a disadvantage regarding productivity according to the results, to determine the final value, the product's quality should also be considered. Therefore, the organoleptic properties of the cinnamon bark under modified planting systems were tested.

According to the results, the oil content of the bark samples obtained from vegetatively propagated plants (2.22 %) was significantly higher ($p < 0.05$) than seedlings (1.24 %) (Figure 5 (A)). Simultaneously, the cinnamaldehyde percentage in the bark oil was also significantly higher ($p < 0.05$) in vegetatively propagated plants (64.50 %) than in seedlings (56.95 %) (Figure 5 (B)). In contrast to the cinnamaldehyde percentage, the percentages of eugenol and cinnamyl acetate were significantly higher in seedlings (eugenol: 4.64 %; cinnamyl acetate: 9.76 %) than in vegetatively propagated plants (eugenol: 2.27 %; cinnamyl acetate: 3.29 %) (Figure 5 (C)). At the same time, the percentages of benzyl benzoate, β-linalool and β-caryophyllene were not significantly affected ($p < 0.05$) by any of the tested factors (Figure 5 (D-F)).

One of the significant drawbacks of cinnamon plants derived from seedings is the inability to maintain superior qualities due to their cross-pollinated nature (Liyanage *et al*. 2021). Unlike seedlings, vegetatively propagated plants can maintain superior qualities obtained from the mother plants. Cinnamon variety Sri Gemunu consist of a higher bark oil content and a cinnamaldehyde content, producing higher quality cinnamon bark (Weerasuriya and Pathirana 2020). As the vegetatively propagated plants of cinnamon variety Sri Gemunu were used for the study, the bark obtained from those plants exhibits superior qualities than seedlings.

CONCLUSIONS

The impact of spatial pattern, planting material and harvesting interval were evaluated on the bark yield, bark dry matter percentage, biological yield, the composition of the biological yield and organoleptic properties of cinnamon. The effect of planting material and spatial pattern (either as an interaction effect or the main factor effect) was significant ($p < 0.05$) for most of the tested attributes. Simultaneously, the impact of harvesting interval was significant ($p < 0.05$) for cumulative bark yield over two years.

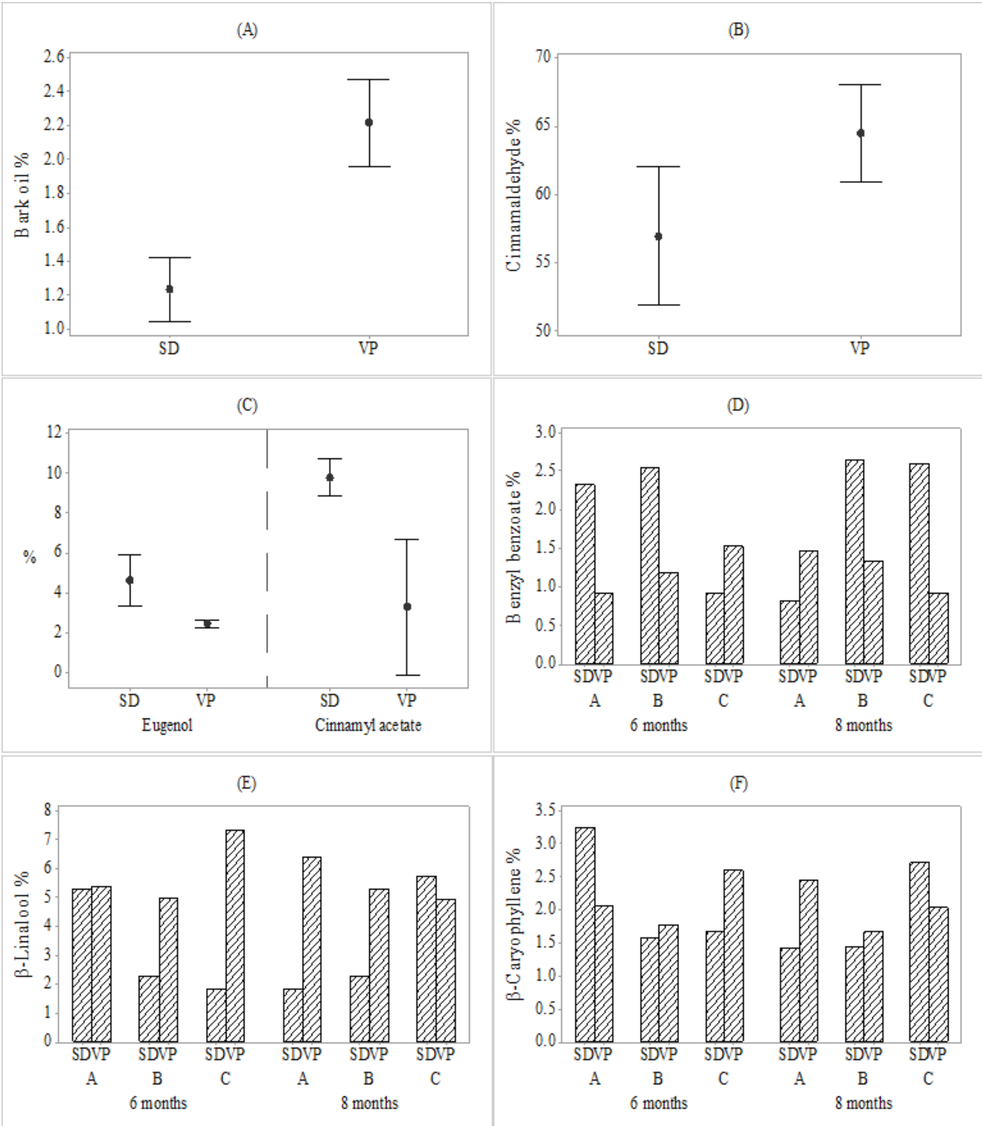

Figure 5: Oil content and availability of some important secondary metabolites in cinnamon bark under modified planting systems. (A): Bark oil content, (B): Cinnamaldehyde %, (C): Eugenol and Cinnamyl acetate %, (D): Benzyl benzoate %, (E): β-Linalool %, (F): β-Caryophyllene % (SD: Seedlings; VP: Vegetatively propagated plants; A: 1.2×0.6, 3 plants/ hill; B: 1.2×0.4, 2 plants/hill, C: 1.2×0.2, 1 plant/hill; 6 months: 6 months harvesting interval; 8 months: 8 months harvesting interval)

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AUTHOR CONTRIBUTION

HNA, DLCKF and CKB conceptualized and designed the study. HNA performed the experiments and analyzed and interpreted the data. HNA and DLCKF contributed to drafting the manuscript. DLCK and CKB critically revised the manuscript.

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