Growth response of patchouli (*Pogostemon cablin* Benth.) seedlings to the application of lamtoro, calliandra, and sengon leaf compost fertilizers

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Abstract. The patchouli plant (*Pogostemon cablin* Benth.) is a natural source of essential oil. It can grow in shaded areas, making it suitable for cultivation in agroforestry systems. Trees such as lamtoro, calliandra, and sengon can serve as components in patchouli-based agroforestry. This research was conducted to assess the impact of compost fertilizers made from three types of leaf litter and to identify which treatment most effectively supported the growth of patchouli seedlings. This study utilized a Completely Randomized Design (CRD) with compost fertilizer as the sole experimental factor, which included four treatment variations. A total of 20 experimental units were obtained by applying five replications for each treatment. The results showed that compost fertilizer had no significant effect on the height of patchouli plants. However, it significantly affected stem diameter, number of leaf blades, number of secondary leaf branches, and both the fresh and dry biomass of the crown and root system. Among all treatments, lamtoro leaf compost yielded the most favorable effect on patchouli seedling growth.

1 Introduction

Indonesia is a tropical country with diverse topographical and climatic conditions. This high level of biodiversity enables Indonesia to host various types of plants that can be utilized to meet a wide range of human needs. However, to this day, Indonesia has not been able to optimally utilize its biological resources, one of which is essential oils compounds produced by medicinal plants. It is estimated that there are around 150–200 species of essential oil producing plants [1]. One of the most promising is patchouli (*Pogostemon cablin* Benth.), which produces patchouli oil. The main compound of patchouli oil is patchouli alcohol, which makes up about 45–50%. Due to its high demand, patchouli cultivation must be optimized to reduce production costs while maintaining high-quality yields. One of the potential plants that can be utilized as a vital oil producer is patchouli (*Pogostemon cablin* Benth.). Patchouli plants yield an essential oil commonly referred to as patchouli oil.

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Patchouli alcohol, which makes up about 45% to 50%, is the primary compound of patchouli oil. The high demand for patchouli oil causes the need for plant cultivation with lower costs and good plant quality to maximize profits.

One strategy to achieve this is through the use of composted organic fertilizer, which can reduce input costs and improve crop quality [2]. Compost is often used as a component of the planting medium and can improve soil productivity by enhancing its physical, chemical, and biological properties [3]. A major challenge in patchouli cultivation is the lack of plant quality and quantity, which is often caused by low soil fertility. Trees such as lamtoro, calliandra, and sengon are potential components of patchouli-based agroforestry systems. These species belong to the Fabaceae family and can form symbioses with *Rhizobium* bacteria to fix atmospheric nitrogen. The nitrogen content from these plants can stimulate microbial development in the soil, and they are often used as intercrops or boundary plants in agroforestry systems.

Pruning is conducted to prevent excessive nutrient use by these trees, and the pruned leaves can be processed into compost [4]. Despite the high economic value of patchouli and the compost potential of lamtoro, calliandra, and sengon leaves, their use as compost in agroforestry-based patchouli cultivation has not been widely applied. This study investigates the influence of compost fertilizers derived from lamtoro, calliandra, and sengon leaves on the growth of patchouli seedlings, aiming to identify the most effective compost type.

2 Method

2.1 Study location

This study took place in the greenhouse of the Forest Ecology and Nursery Division, Silviculture Department, Faculty of Forestry and Environment, IPB University, between August and December 2024.

2.2 Research procedures

Lamtoro, calliandra, and sengon leaves were collected from stands located in the campus area of Bogor Agricultural University. The collected leaves were sun-dried for 1–2 weeks. Once dried, the leaves were placed into 80-liter drums and mixed with water, EM4, and brown sugar until evenly distributed. The ratio between the leaves, EM4, and brown sugar solution was 50:1:1 (v/v/v). The addition of EM4 and brown sugar serves to improve the physical characteristics of the compost, eliminate foul odors, and accelerate the decomposition process. The composting period lasted for 30 days until the compost reached maturity [5].

Indicators of mature compost include a change in color to blackish brown, an earthy smell that replaces the previous foul odor, and a moist, fine, crumbly texture. Compost typically decreases in weight by up to 50% from the original material. Ideal compost texture remains moist and crumbly but does not release water when squeezed.

Patchouli seedlings were obtained from the Center for Testing Standard Instruments for Medicinal Spices and Aromatic Plants, Bogor, totaling 20 seedlings. All seedlings used in this study had a uniform number of leaflets (six per seedling) and a relatively consistent height of approximately 20 cm. The seedlings were planted in 20 × 20 cm polybags. The growing media composition was as follows: for the control treatment, soil without compost was used, while for the fertilizer treatments, the media consisted of a 2:1 mixture of soil and compost.

Plant maintenance included irrigation and weed control. The plants were watered twice daily, once in the morning and once in the evening. Weeding was performed weekly by removing weeds around the polybags and monitoring any signs of pest or disease infestation. Data collection involved measurements of plant height, stem diameter, number of leaves, fresh weight of the crown and roots, and dry weight of the crown and roots. Observations were carried out for 9 weeks after planting.

2.3 Data analysis

This study applied an experimental approach based on a Completely Randomized Design (CRD), using compost fertilizer (K) as the sole treatment factor, which comprised four levels. A total of 20 experimental units (individual plants) were used. Data was analyzed using analysis of variance (ANOVA), with the aid of Microsoft Excel and IBM SPSS Statistics 22. Hypothesis testing was conducted by comparing the calculated F value (F count) with the critical F value (F table). The null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) accepted if F count exceeded F table; otherwise, H_0 was retained. If the treatment effect was found to be statistically significant, further analysis was conducted using the Duncan Multiple Range Test (DMRT).

3 Results and discussion

3.1 Plant height of patchouli

Plant height is one of the most commonly used parameters to assess plant growth response to treatment. An increase in plant height reflects the vegetative growth activity of a plant. It is often used as an indicator of growth and as a parameter for evaluating the effects of environmental factors or applied treatments [6]. Plant height is influenced by the nutrient content in the growing medium, particularly nitrogen (N). Nitrogen plays a crucial role in stimulating overall plant growth, especially in the development of stems, branches, and leaves. Figure 1 illustrates the growth trend of patchouli plant height, while Table 1 presents the summarizes of the Duncan test results.

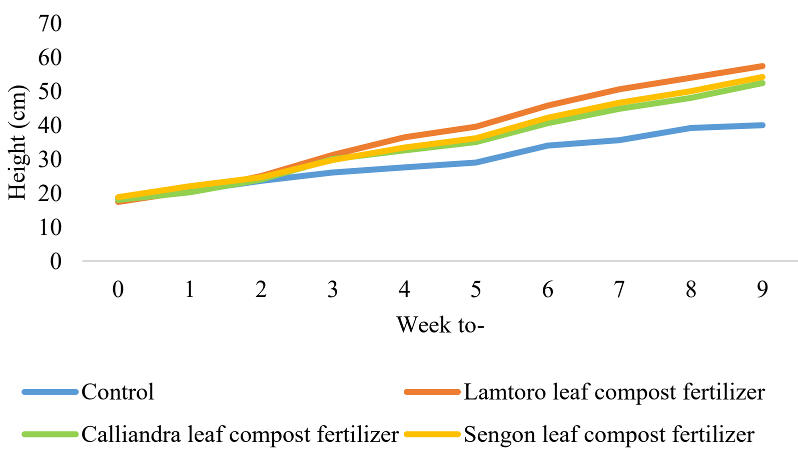

Fig. 1. Average plant height of patchouli.

Table 1. Summary of Duncan test results for plant height of patchouli over a 9-week period

No	Treatment	Plant height (cm)
1	Control	29,42[a]
2	Lamtoro leaf compost treatment	37,80[a]
3	Calliandra leaf compost treatment	34,56[a]
4	Sengon leaf compost treatment	35,78[a]

Values within the same column sharing the same letter are not significantly different at the 95% confidence level.

3.2 Stem diameter of patchouli

Continuous plant growth reflects the ongoing processes of cell division and enlargement. Stem diameter is influenced by nutrient availability, particularly macronutrients. In patchouli plants, stem diameter growth serves as a key indicator for assessing plant development and overall health. An increase in stem diameter is directly associated with greater biomass accumulation. A larger stem diameter allows patchouli plants to support more branches, leaves, and roots, thereby enhancing the potential yield of patchouli essential oil.

Table 2 summarizes the Duncan test results for stem diameter growth in patchouli plants. The results indicate that the control treatment and the application of lamtoro leaf compost fertilizer produced significantly different effects. In contrast, the calliandra leaf compost treatment did not differ significantly from the sengon leaf compost treatment.

Table 2. Summary of Duncan test results for stem diameter growth of patchouli over a 9-week period

No	Treatment	Plant Diameter (cm)
1	Control	5,46[a]
2	Lamtoro leaf compost treatment	6,51[b]
3	Calliandra leaf compost treatment	5,99[ab]
4	Sengon leaf compost treatment	5,89[ab]

Values within the same column sharing the same letter are not significantly different at the 95% confidence level.

Figure 2 shows the average increase in stem diameter of patchouli plants. Based on these results, plants treated with lamtoro leaf compost fertilizer exhibited greater stem diameter growth than those in the control treatment as well as those treated with calliandra and sengon leaf compost. Stem diameter enlargement occurs through cell division driven by lateral meristem activity, which is supported by the availability of nutrients that plants can absorb to facilitate growth.

Nitrogen (N) is essential for vegetative plant growth, as it stimulates overall development, particularly in stems, branches, and leaves. Lamtoro leaves contain 3,84% nitrogen (N); 0,2% phosphorus (P); 2,06% potassium (K); 1,31% calcium (Ca); 0,33% magnesium (Mg), 0,584% organic carbon (C-organic), and have a pH of 4,4 [7,8]. Nitrogen is essential for the formation of proteins, nucleic acids, and chlorophyll compounds that are vital for supporting plant growth. In general, higher nitrogen concentrations are associated with greater plant growth potential.

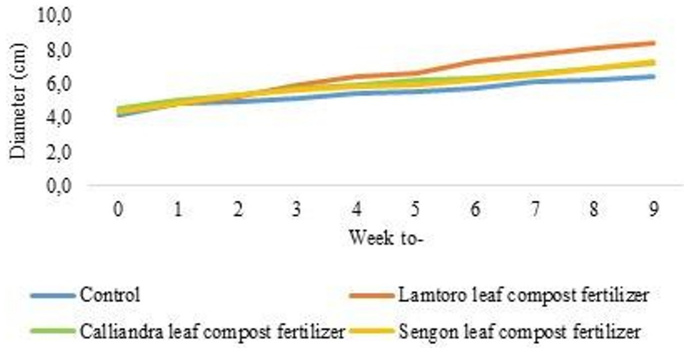

Fig. 2. Average stem diameter of patchouli plants.

3.3 Number of leaflets in patchouli

Leaves are vital organs in plants, playing important roles in photosynthesis, respiration, transpiration, and assimilation, as well as serving as sites for gas exchange through stomata. Characteristics such as being thin, broad, and rich in chlorophyll support efficient sunlight absorption for optimal assimilate production. The greater the number of leaves, the higher the plant's capacity for photosynthesis. In patchouli plants, the number of leaves directly influences the yield of essential oil. Although essential oils are produced in various parts of the plant including roots, stems, stalks, and leaves the highest concentration is found in the leaves.

The Duncan test results presented in Table 3 show that the control treatment differed significantly from the lamtoro leaf compost fertilizer treatment. The composted calliandra leaf treatment was not significantly different from the treatment using composted sengon leaves. Among all treatments, the application of lamtoro leaf compost produced the highest number of leaves.

Table 3. Summary of Duncan test results for number of leaflets of patchouli over a 9-week period

No	Treatment	Number of leaves
1	Control	20,18^{a}
2	Lamtoro leaf compost treatment	48,42^{b}
3	Calliandra leaf compost treatment	36,24^{ab}
4	Sengon leaf compost treatment	33,80^{ab}

Values within the same column sharing the same letter are not significantly different at the 95% confidence level.

Figure 3 presents the average number of leaflets under different compost treatments over a 9-week planting period. The results indicate that compost fertilizer made from lamtoro leaves produced the highest number of leaflets among all treatments. This suggests that the application of lamtoro leaf compost can enrich the planting medium with nutrients, thereby enhancing plant growth.

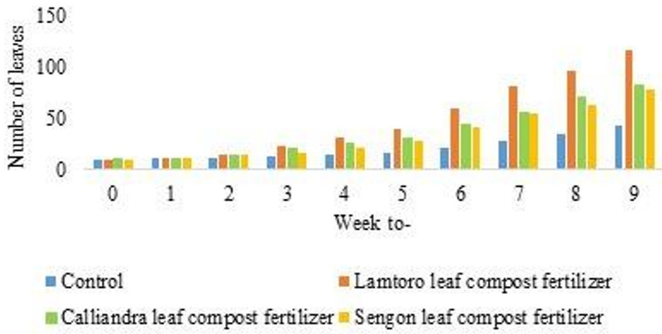

Fig. 3. Average number of leaflets of patchouli plants.

Overall, compost fertilizer application led to an increased number of leaves relative to the control treatment (Figure 4). The use of composted organic fertilizer can improve soil conditions, making them more fertile and richer in beneficial microorganisms. Due to its slow decomposition process, compost fertilizer releases nutrients gradually, making them available to plants over a longer period and thereby potentially increasing crop yields. In contrast, plants in control treatment relied solely on water and the nutrients already present in the soil, without any additional nutrient input.

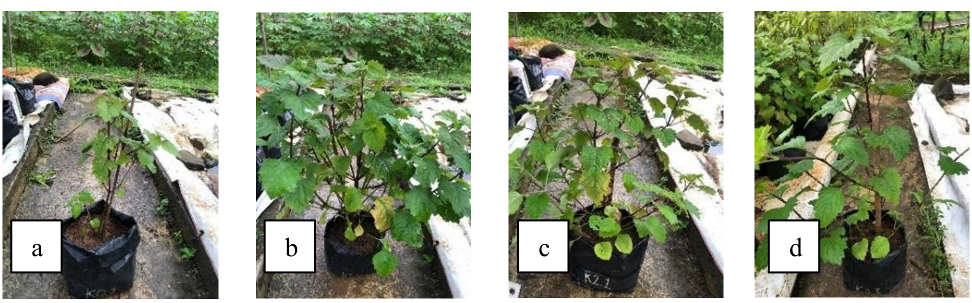

Fig. 4. Comparison of the number of leaflets at the end of the observation. (a) control, (b) lamtoro leaf compost, (c) calliandra leaf compost, (d) sengon leaf compost.

Plants treated with lamtoro leaf compost produced more leaflets than those treated with calliandra and sengon leaf compost. The nitrogen (N) content in lamtoro leaves is 3,84% [9], while calliandra contains 2,1% and sengon only 0,23% nitrogen [9,10]. Nitrogen is a primary macronutrient essential for plant growth, particularly in the development of leaves and plant tissues. Patchouli plants require a relatively high amount of nitrogen to achieve optimal growth. As a legume, lamtoro has a high nitrogen content and decomposes more rapidly than calliandra and sengon. The greater availability of nitrogen from lamtoro compost significantly supports improved growth in patchouli plants.

3.4 Number of secondary leaves branches of the patchouli plants

Fertilization supports the vigorous growth of patchouli plants, promotes leaf development, and enhances yield. In patchouli, the leaves contain the highest concentration of essential oil compared to other plant parts, making the formation and increase of secondary leaf branches particularly important. Branching is strongly influenced by factors that promote rapid vegetative growth, especially adequate moisture and sufficient nitrogen availability.

The results of Duncan's test (Table 4) showed that the lamtoro leaf compost fertilizer treatment produced significantly different results compared to the control. Meanwhile, the composted calliandra leaf treatment did not show a statistically significant difference from the composted sengon leaf treatment. Among all treatments, lamtoro leaf compost resulted in the highest number of secondary leaf branches.

Table 4. Summary of Duncan test results for number of secondary leaf branches of patchouli over a 9-week period

No	Treatment	Number of secondary leaves
1	Control	0,20^{a}
2	Lamtoro leaf compost treatment	8,80^{c}
3	Calliandra leaf compost treatment	4,60^{b}
4	Sengon leaf compost treatment	3,20^{b}

Values within the same column sharing the same letter are not significantly different at the 95% confidence level.

The findings revealed that lamtoro leaf compost fertilizer promoted the highest growth of secondary leaf branches compared to the control, calliandra, and sengon compost treatments. As shown in Figure 5, the lamtoro compost treatment began producing secondary leaf branches as early as the fourth week of observation. Lamtoro leaf compost contains nitrogen and other essential nutrients that support the growth of secondary leaf branches. The development of leaf branching is strongly influenced by adequate moisture and sufficient nitrogen availability [11].

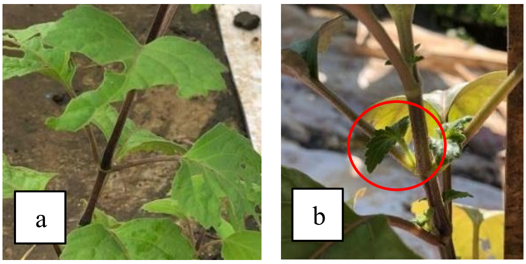

Fig. 5. Comparison of the number of secondary leaf branches in the 4 week of observation. (a) control, (b) lamtoro leaf compost fertilizer.

The number of secondary leaf branches is positively correlated with the number of leaflets. As the number of leaf branches increases, the number of leaflets also increases accordingly. A higher number of secondary branches in patchouli plants leads to more growth points, which eventually develop into young leaves rich in oil glands. This is consistent with the observations on the number of leaflets (Table 3), where patchouli plants treated with lamtoro leaf compost produced the highest number of leaves. Leaves are the primary target organ in patchouli plants for essential oil production.

3.5 Fresh weight of patchouli plants

Growth is a fundamental aspect of plant development that can occur at the cellular, tissue, organ, or whole-plant level. At the organ level, growth is commonly measured through increases in fresh weight. Water is an essential component of plant life, and the plant's water requirement varies depending on its growth phase and type. Water forms the main constituent of protoplasm and accounts for approximately 85–90% of a plant's fresh weight. Fresh weight reflects both the accumulation of photosynthates stored in biomass and the water content found in stems, leaves, and roots [12].

Analysis of variance indicated that compost fertilizer treatment had a significant effect on the fresh weight of patchouli plants. Accordingly, Duncan's Multiple Range Test (DMRT) was conducted as a post hoc analysis to identify significant differences among the treatments. The results of the Duncan test for fresh weight are presented in Table 5.

Table 5. Summary of Duncan test results for fresh weight of crown and roots of patchouli over a 9-week period

No	Treatment	Crown FW (g)	Root FW (g)	Total FW (g)
1	Control	27,64^{a}	24,61^{a}	52,25^{a}
2	Lamtoro leaf compost treatment	77,29^{c}	185,25^{c}	262,54^{c}
3	Calliandra leaf compost treatment	45,09^{ab}	108,42^{b}	153,51^{b}
4	Sengon leaf compost treatment	62,96^{bc}	87,60^{b}	150,56^{b}

Values within the same column sharing the same letter are not significantly different at the 95% confidence level. FW= fresh weight

The results of Duncan's test showed that the application of compost fertilizers derived from lamtoro, calliandra, and sengon leaves significantly affected crown fresh weight, root fresh weight, and total fresh weight compared to the control. These differences indicate that each type of compost has a significant influence on plant growth. Among all treatments, the application of lamtoro leaf compost resulted in the highest crown and root fresh weights. This is likely due to the efficient absorption of nutrients from organic matter by the plants, particularly nitrogen, which plays a crucial role in supporting plant growth.

An effective composting process also contributes to increased fresh weight yield in patchouli plants. In this study, compost was prepared using an activator solution with a ratio of 50:1:1 (v/v/v) for water, EM4, and brown sugar. The small proportion of EM4 and brown sugar is sufficient to optimally activate mycobacterial fermentation, allowing the formulation to produce high-quality compost that is easily absorbed by plants [13].

The more water and nutrients a plant absorbs, the greater the production of photosynthates, which in turn increases the plant's fresh weight. Photosynthates also serve as food reserves and play a crucial role in supporting overall plant growth. The number of leaflets directly influences the rate of photosynthesis. A higher leaflet count increases the surface area for photosynthesis, as more leaves provide more stomata for gas exchange. Consequently, a greater number of leaflets leads to increased fresh weight. This finding aligns with the results in Table 3, which show that patchouli plants treated with lamtoro leaf compost fertilizer exhibited the highest increase in leaflet number, contributing to a higher fresh weight. In general, better plant growth is associated with an increase in fresh weight [14].

3.6 Dry weight of patchouli plants

Dry weight is an important indicator of plant growth, as it reflects the accumulation of organic compounds resulting from photosynthesis. It is measured after the plant has been dried to remove all water content, leaving only the organic matter produced through metabolic processes. Patchouli is one of the plants that produces essential oil. Measuring dry weight in patchouli plants is critical for essential oil production, as it is directly related to both the yield and quality of the oil produced.

The results of analysis of variance indicated that compost fertilizer treatment had a significant effect on the dry weight of patchouli plants. As a result, Duncan's Multiple Range Test was applied to further examine the differences among the treatment groups. The results of the Duncan test for dry weight are presented in Table 6.

Table 6. Summary of Duncan test results for fresh weight of crown and roots of patchouli over a 9-week period.

No	Treatment	Crown DW (g)	Root DW (g)	Total DW (g)
1	Control	3,52[a]	4,17[a]	7,69[a]
2	Lamtoro leaf compost treatment	14,10[c]	29,44[c]	43,55[c]
3	Calliandra leaf compost treatment	6,59[ab]	15,97[b]	22,56[b]
4	Sengon leaf compost treatment	8,71[b]	12,98[b]	21,70[b]

Values within the same column sharing the same letter are not significantly different at the 95% confidence level. DW= dry weight

The Duncan test results show that the application of all three types of compost fertilizer affected the crown dry weight, root dry weight, and total dry weight of patchouli plants. An increased dry weight signifies strong vegetative growth, suggesting that the plant has efficiently absorbed water and nutrients from the soil to support its physiological functions [15]. Crown dry weight reflects the level of nutrients absorbed by the plant and the efficiency of its physiological processes, while root dry weight indicates the plant's ability to absorb water effectively.

Patchouli plants treated with lamtoro leaf compost fertilizer produced the highest average crown and root dry weights compared to other treatments. The nitrogen content in the compost supports optimal plant growth. As a component of proteins, nitrogen functions as a biological catalyst that accelerates metabolic processes in plants. Lamtoro leaf compost can enhance the physiological efficiency of patchouli plants and improve their resistance to environmental conditions. Plant dry weight represents the biomass formed through the accumulation of photosynthates produced via photosynthesis. Based on Table 3, the lamtoro leaf compost treatment resulted in the highest number of leaflets. Consequently, it also produced the highest crown dry weight. The number of leaf blades can influence dry weight, as leaves are the primary site for photosynthate accumulation.

4 Conclusion

The application of compost made from lamtoro, calliandra, and sengon leaves had a significant effect on several growth parameters of patchouli plants, including stem diameter, number of leaflets, number of secondary leaf branches, fresh weight, and dry weight. However, it did not have a significant effect on plant height. In general, the application of compost fertilizer enhanced patchouli plant growth compared to the control treatment. Among all treatments, lamtoro leaf compost fertilizer produced the best growth performance, with an average stem diameter of 6,51 cm; an average of 48,42 leaflets; 8,80 secondary leaf branches, a total fresh weight of 262,54 g; and a total dry weight of 43,55 g.

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