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(RESEARCH ARTICLE)

Influence of adding *Eucalyptus* litter and mixed litter on planting media to growth of *Calliandra* Seedlings (*Calliandra calothyrsus*)

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Abstract

The rapid depletion of fossil fuel reserves and the resulting environmental degradation have necessitated the transition to renewable biomass energy, such as wood pellets derived from Calliandra (*Calliandra calothyrsus*). The success of Calliandra cultivation as a raw material for bioenergy is highly dependent on the quality of the growth media during the early seedling stage. This research aimed to evaluate the effectiveness and growth response of *Calliandra calothyrsus* seedlings to the addition of *Eucalyptus* litter and mixed litter in the planting media. The research was conducted at the Forestry Management and Watershed Rehabilitation shading area of Bukit Asam Public Company using a one-factor Completely Randomized Design with five treatments: T0 (100% top soil), T1 (25% *Eucalyptus* litter + 75% top soil), T2 (50% *Eucalyptus* litter + 50% top soil), T3 (25% mixed litter + 75% top soil), and T4 (50% mixed litter + 50% top soil). Growth parameters, including plant height and the number of leaf stalks (petioles), were monitored over a 14-day observation period. Analysis of Variance (ANOVA) revealed that the treatments significantly influenced both seedling height ($p = 0.0083$, which is $p < 0,05$) and petiole production ($p = 0.0000053$, which is $p < 0,05$). Post-hoc Tukey's HSD tests indicated that T4 (50% mixed litter) achieved the highest growth performance in height, while T3 (25% mixed litter) produced the greatest number of leaf stalks. The superior performance of mixed litter treatments is attributed to accelerated decomposition and mineralization rates, which enhance nutrient availability and soil porosity. Conversely, treatments involving *Eucalyptus* litter (T1 and T2) showed lower growth compared to the control. This inhibition is likely caused by the high lignin content of fresh *Eucalyptus* leaves, which slows decomposition, and the presence of allelopathic polyphenols that suppress cell division and mitotic activity. This research concludes that mixed organic litter is more effective for optimizing *Calliandra calothyrsus* seedling growth and recommends a longer decomposition period to neutralize allelopathic risks in *Eucalyptus*-based media.

Keywords: *Calliandra calothyrsus*; Mixed litter*; Eucalyptus* litter; Planting media; Seedling growth

1. Introduction

Mining activities are carried out to obtain source energy primary based fossil for example, coal is used in various sectors, including power generation and transportation. However, this mining process has the potential to damage ecosystems and disrupt the balance of biodiversity. Furthermore, the use of fossil fuels also has negative impacts on the environment. between other increase emission carbon dioxide, causing acid rain, damaging the ozone layer and further increasing the impact of global warming (Pramudiyanto and Sued, 2020).

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High levels of exploration, significant energy consumption, and future population growth are expected to render fossil fuel reserves insufficient to meet increasing energy needs. Experts predict that if current energy consumption patterns persist, fossil fuel reserves will rapidly deplete. Oil is expected to run out by 2052, natural gas by 2060, and coal by 2090. Therefore, the search for more environmentally friendly and sustainably sourced energy is necessary. Biomass become Wrong One Renewable energy can play a role in reducing dependence on fuel imports and strengthening a country's energy independence (Parinduri *et al*., 2020).

Biomass is organic material formed from the photosynthesis process of plants. Its sources can be wood waste, agricultural waste, plantation, results forests, as well as household and industrial organic waste. Biomass can be considered an alternative energy source that can replace fossil fuels. In general, the biomass used as material burn is the remaining main production results or have low economic value (Ridhuan *et al*., 2019).

The use of bioenergy can be directed to produce renewable energy, one of which is production *pellet* from biomass wood. This conversion process has advantages, including increasing the calorific value per unit volume, simplifying storage and distribution, and producing. energy renewable and sustainable development that can help reduce greenhouse gas emissions and reduce pollution. One of them plant Which potential as material *pellet* raw materials wood is Calliandra (Mauritio *et al*., 2022)

Bukit Asam Public Company launched *a pilot plant for wood pellets* made from red *Calliandra* wood pellets, which are used as a fuel mixture for coal in a steam-fired power plant with a production capacity of 200 tons *per year.* According to research by Hidayatullah *et al*. (2022), *Calliandra* show mark heat pellets range from 4522.20-4617.20 cal/g with a raw material particle size of 60-80 *mesh* which has met SNI 8675:2018I and DIN 51731. The high calorific content makes *Calliandra* a potential candidate to replace fossil fuels in the combustion process.

Calliandra (*Calliandra calothyrsus*) is a type of legume with a fairly fast growth rate, capable of growing up to 2 m in just 2-3 months (Hendrati and Nurromah, 2019). The condition of the growing medium greatly influences the vegetative growth of *Calliandra* seedlings. Addition litter on media planting can increase the availability of nutrients (Maulidya and Widiyanto, 2023). Along Over time, the litter will decompose and add organic matter to the planting medium, thereby helping to maintain and improve soil fertility (Watumlawar *et al., 2019).* This research aims to determine the effectiveness and response of adding *Eucalyptus* litter and mixed litter to the planting medium on the growth of *Calliandra (Calliandra calothyrsus)* seedlings.

2. Materials and Methods

2.1. Experimental site and duration

This research done on date 16 June 2025 to 31 July, 2025. Located at the shading area Forestry Management and Watershed Rehabilitation location, Bukit Asam Public Company, Tanjung Enim, Muara Enim Regency, South Sumatra.

2.2. Tools and materials

The tools used in this research were writing instruments, a camera, a ruler, and polybags. The materials used included seeds *Calliandra* (*Calliandra calothyrsus*) which has the same size and number of mother stalks, mixed litter from various tree species in region ID 16, *Eucalyptus* litter, and top soil.

2.3. Research design

This research used a one-factor Completely Randomized Design (CRD). The factors tested were the composition of the planting media T0 (100% top soil) as a control, T1 (25% *Eucalyptus* litter + 75% top soil), T2 (50% *Eucalyptus* litter + 50% top soil), T3 (25% mixed litter + 75% *top soil*), and T4 (50% mixed litter + 50% top soil) and combined with 5 times repetition so that produced 15 experimental unit.

2.4. Experimental design and statistical analysis

A total of 25 *Calliandra calothyrsus* seedlings with uniform height (8 cm) and leaf stalk count (6 stalk) were selected for the research. The seedlings were planted in polybags filled with different growing media: top soil as the control, and treatments T1 to T4 consisting of 25% and 50% concentrations of *Eucalyptus* litter and mixed litter, respectively. All plants were watered twice daily. Parameters including plant height and the number of leaf stalks were observed for two weeks, following the modified protocol of Rahmania and Nahlunnisa (2020). Data were analyzed using One-Way ANOVA, followed by Tukey's Honestly Significant Difference (HSD) test at a 5% significance level where treatment effects were significant.

3. Results

3.1. Height and leaf stalk number (petioles) average

Based on the results of the average of height and leaf stalk number (petioles) in the treatment of adding *Eucalyptus* litter and mixed litter to the planting media with different compositions, it is presented in Table 1 as follows:

Table 1 Height and leaf stalk number (petioles) average

Treatments	Parameter (average)	
	Seedling Height (cm)	Petioles Number
T0 (100% top soil)	9,171	7,114
T1 (25% *Eucalyptus* litter + 75% top soil)	9,646	6,714
T2 (50% *Eucalyptus* litter + 50% top soil)	8,757	6,571
T3 (25% mixed litter + 75% top soil)	9,954	8,742
T4 (50% mixed litter + 75% top soil)	9,574	8,428

3.2. Growth performance: height and number of leaf stalks (petioles)

The changes in plant height over the two-week observation period are illustrated in Figure 1.

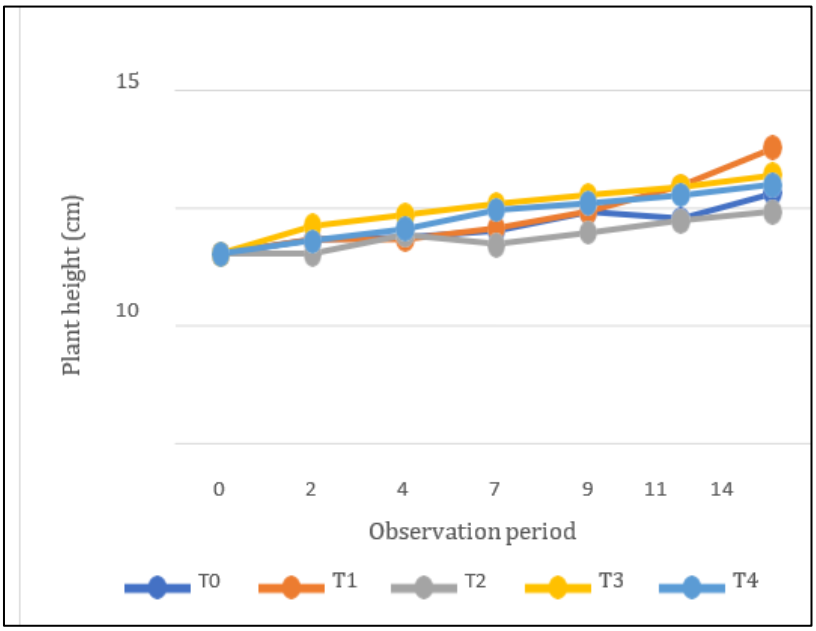

Figure 1 Chart of plant height

The results of observations of the leaf stalks (petioles) number on plants are presented in Figure 2.

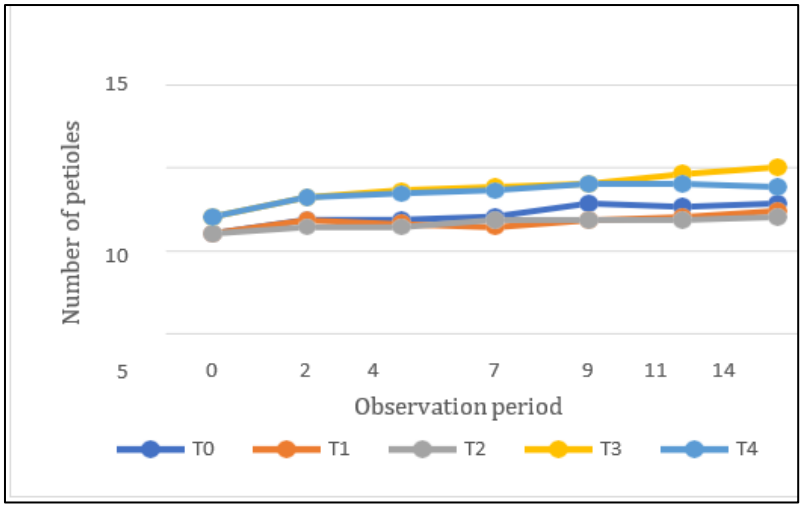

Figure 2 Chart of petioles number

3.3. Significance of treatments on plant height

The results of the HSD test are summarized in Table 2 below:

Table 2 Tukey's HSD test results for the plant height of *C*alliandra *calothyrsus* seedlings

Treatments	Average	Notation
T0	8,640	a
T2	9,2288	a
T3	9,438	a
T1	9,631	a
T4	9,954	b

Note: Post-hoc comparisons (Tukey's HSD) indicated that T4 was significantly different from the control (T0) ($p < 0,05$). However, no significant differences were observed between control T0 and T1, T2, T3, nor between T1 and T4 ($p > 0,05$)

3.4. Significance of treatments on leaf stalk production

The results of ANOVA analysis are presented in Table 3 below:

Table 3 Tukey's HSD test results for leaf stalk production (petioles) of *Calliandra calothyrsus* seedlings

Treatments	Average	Notation
T2	6,552	a
T1	6,714	a
T0	7,114	a
T4	8,486	b
T3	8,771	b

Note: Post-hoc comparisons (Tukey's HSD) indicated no significant differences between T0 and T1, T2, or between T3 and T4 ($p > 0,05$). However, a significant difference was observed between T0, T1, T2 and T3, T4 ($p < 0,05$)

4. Discussion

The results indicated that treatment T3 (25% mixed litter + 75% top soil) yielded the highest plant growth in terms of average height after the two-week observation period. The observed growth trend, ranked from highest to lowest, was

as follows: T3 > T1 > T2 > T4 > T0. Although the adding of litter generally exerted a positive effect on plant height, the differences between the control (T0) and the treated plants were marginal. This minimal variance can be attributed to the specific concentration of litter applied and the associated rate of decomposition. As the quantity of added litter increases, the demand for microbial decomposition also rises. The two-week experimental duration was likely insufficient for complete mineralization of the organic matter. Furthermore, incomplete decomposition can lead to nutrient immobilization, where the microbial population consumes available soil nutrients to break down complex carbon structures, thereby limiting nutrient availability for plant uptake. As noted by Saibi and Tolangara (2017), litter must undergo complete decomposition to release essential nutrients in forms readily absorbable by plants. Consequently, the beneficial effects of the organic amendments in this research were likely constrained by the short experimental timeframe.

Observation results regarding the increase in height from day 2 to day 14 show the increase in height on T1 media reached 12.5 cm with average increase in height was 4.4 cm, T3 reached 11.36 cm with average addition of 3.36 cm, T4 reached 10.94 cm with average increase in height of 2.94 cm, T0 reached 10.6 cm with average addition height 2.26 cm, T2 reached 9.8 cm with average addition of 0.4 cm. T2 treatment was not better than T0 which media was 100% top soil. This is because top soil contains organic materials that can be utilized by plants but requires the addition of other organic materials to support plant growth faster. This statement is reinforced by Syifa *et al*. (2025), statement that good *top soil quality can determine plant height.* Top soil is generally darker in color than the lower layers or previous horizons because this layer contains accumulated organic matter, which provides nutrients that support plant growth.

Meanwhile, the average increase in the number of leaves in a way consecutive from which most to least, namely T3, T4, T0, T1 and T2. This means that the treatment of adding *Eucalyptus* litter that is T1 and T2 no better than T0 (100% top soil). This is due to the nutrients contained in *Eucalyptus* litter like phosphorus (P) is more important for plant growth. According to Khan *et al.* (2023), *phosphorus*, whether deficient or excessive, can influence stem elongation, and preventing stunting. This is because phosphorus plays a role in cell division in the apical meristem (stem tip).

The observation of leaf stalk numbers (petioles) in *Calliandra calothyrsus* seedlings revealed a consistent increase from day 2 to day 14. Seedlings grown in media T3 and T4, which incorporated mixed litter, exhibited the most significant enhancement in petioles development. This superior growth can be attributed to the advanced decomposition rate of the mixed litter compared to the *Eucalyptus*-only treatments. The *Eucalyptus* litter used in this research was collected in a relatively fresh state, characterized by high lignin content, particularly within the stalks. This condition is known to hinder the breakdown of organic matter. These findings align with Saptiningsih and Haryanti (2015), who stated that high level of lignin and cellulose extend the decomposition period. The presence of such recalcitrant organic materials increases the soil C/N ratio, leading to high microbial activity that may cause temporary nutrient immobilization. Consequently, in treatments with slower decomposition, essential nutrients become less available for immediate plant uptake during the early stages of growth.

The application of *Eucalyptus* litter in treatments T1 (25% *Eucalyptus* litter + 75% top soil) and T2 (50% *Eucalyptus* litter + 50% top soil) resulted in a lower petiole count compared to the control (T0). This disparity is likely due to the nutrient dynamics within the growth media, where the top soil typically exhibits a higher nitrogen (N) to phosphorus (P) ration. Such a nutrient balance often shifts the plant's physiological focus toward leaf development and biomass accumulation. This observation is consistent with the findings of Zhang *et al*. (2021), who reported that increased nitrogen availability enhances photosynthetic capacity and improves water-uses efficiency, both of which are critical drivers for leaf growth. However, in the context of this research, the specific nutrient proportions in the *Eucalyptus*-amended media may have favored vegetative expansion over the proliferation of new petioles during the initial observation phases.

The Analysis of Variance (ANOVA) indicated that incorporation of *Eucalyptus* litter and mixed litter as growth media had a significant effect on the height of *Calliandra calothyrus* seedlings ($p = 0{,}0083$, which is $p < 0{,}05$). Due to these significant differences, a post-hoc Tukey's Honestly Significant Difference (HSD) test was performed to compare treatment averages.

Post-hoc analysis revealed that mixed litter treatments (T3 and T4) differed significantly from the *Eucalyptus* litter treatments (T1 and T2) and the control (T0). Specifically, T3 and T4 exhibited superior growth performance, which can be attributed to the accelerated decomposition rate of the mixed organic matter compared to the pure *Eucalyptus* litter. This faster decomposition facilitates the mineralization process, making essential nutrients more readily available for plant uptake. In the mixed litter treatments, the organic material had been effectively broken down and integrated into the soil matrix. In contrast, the *Eucalyptus* litter remained largely in the form of dry, undecomposed leaves, which limited its contribution to soil fertility during the research period. These observations align with the criteria established by

Siarudin and Rachman (2008), who noted that full decomposed litter typically resembles compost-characterized by a loss of its original structure, a dark or blackish coloration, and a friable, crumbly texture. Consequently, the advanced physical and chemical breakdown of mixed litter provided a more conducive environment for the development of *Calliandra calothyrsus* seedlings.

The Analysis of Variance (ANOVA) revealed that the application of *Eucalyptus* and mixed litter as growth media significantly influenced the number of leaf stalks (petioles) in *Calliandra calothyrsus* seedlings ($p = 0,0000053$, which is $p < 0,05$). Given the significance of these results, a post-hoc Tukey's Honestly Significant Difference (HSD) test was performed to determine specific treatment differences.

The post-hoc Tukey's HSD test revealed significant variations in the leaf stalk (petioles) number of *Calliandra calothyrsus* seedlings across different growing media. Specifically, the T3 and T4 media (mixed litter) outperformed the T0 (control), T1 and T2 (*Eucalyptus* based) treatments. While T3 achieved the highest average leaf stalk (petioles) count, the difference between T3 and T4 was not statistically significant. Conversely, no significant differences were observed among the T0, T1, and T2 treatments. The inferior performance of the *Eucalyptus*-amended media (T1 and T2) compared to mixed litter treatments is likely attributed to allelopathic interference. *Eucalyptus* litter is known to contain high concentrations of polyphenols, which exert allelopathic effects that inhibit plant growth. These findings are supported by Tampubolon *et al*. (2018), who observed that phenolic compounds can suppress cell division and inhibit the rate of mitotic activity within plant tissues. Consequently, the presence of these compounds in the *Eucalyptus* litter likely restricted organogenesis, resulting in lower number of leaf stalks (petioles) compared to the more balanced nutrient environment provided by the mixed litter treatments (T3 and T4).

5. Conclusion

In conclusion, the growth performance of *Calliandra calothyrsus* seedlings is significantly influenced by the composition of the planting media. Among the tested treatments, T4 (50% mixed litter + 75% top soil) demonstrated the most favorable results in terms of seedling height, primarily due to improved nutrient availability, soil porosity, and aeration compared to other media compositions. Furthermore, the number of leaf stalks (petioles) was significantly higher in the mixed litter treatments (T3 - 25% mixed litter + 75% top soil and T4 - 50% mixed litter + 75% top soil) than in the *Eucalyptus*-based treatments (T1 - 25% *Eucalyptus* litter + 75% top soil and T2 - 50% *Eucalyptus* litter + 50% top soil). The lower growth performance observed in T1 dan T2 treatments are attributed to the presence of allelopathic compounds (polyphenols) within the *Eucalyptus* litter, which are due to incomplete decomposition, likely hindered seedling development. These findings underscore the importance of utilizing well-decomposed organic matter to mitigate allelopathic risks and optimize nutrient release for seedling growth. Future studies should focus on determining the optimal decomposition period required to neutralize allelopathic substances in *Eucalyptus* litter for agricultural applications.

Recommendation

Further research should study rigorously address the decomposition dynamics of *Eucalyptus* litter by extending the observation period to facilitate complete organic matter breakdown and nutrient mineralization. To enhance the precision of morphological assessments, future research should standardize seedling preparation within a controlled nursery setting, thereby minimizing potential measurement biases and ensuring more consistent growth data. Additionally, incorporating physiological and biomass-related parameters specifically fresh and dry biomass accumulation is essential to provide a comprehensive evaluation of seedling growth responses to diverse planting media.

Compliance with ethical standards

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Disclosure of conflict of interest

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they

have approved the final version. Additionally, there are no conflicts of interest in connection with this paper, and the material described is not under publication or consideration for publication elsewhere.

Statement of ethical approval

Ethical approval for this research in compliance with international standards as obtainable in Sriwijaya University, Indralaya, Palembang, South Sumatra, Indonesia, was sought and obtained before embarking on this research.

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