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Effect Of Growing Medium Composition And Composting Duration Of Sea Casuarina Leaf Waste On The Growth And Yield Of Red Lettuce (Latuca sativa L. var. Red Rapid)

Pengaruh Komposisi Media Tanam Dan Lama Pengomposan Limbah Daun Cemara Laut Terhadap Pertumbuhan Dan Hasil Tanaman Selada Merah (*Latuca sativa* L. var. Red Rapid)

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ABSTRAK

Penelitian ini bertujuan untuk mengetahui interaksi dan pengaruh komposisi media tanam serta lama pengomposan limbah daun cemara udang (Casuarina equisetifolia L.) terhadap pertumbuhan dan hasil selada merah (Lactuca sativa L. var. Red Rapid), sekaligus untuk mengevaluasi potensi pemanfaatan limbah daun cemara udang sebagai bahan kompos alternatif. Penelitian ini disusun menggunakan Rancangan Acak Kelompok (RAK) faktorial dengan dua faktor: komposisi media tanam (K0 = 2:1:0, K1 = 2:1:1, K2 = 2:1:2, K3 = 2:1:3) dan lama pengomposan (L1 = 14 hari, L2 = 28 hari, L3 = 42 hari). Sebanyak 12 kombinasi perlakuan diulang sebanyak tiga kali, sehingga menghasilkan 36 unit percobaan. Hasil penelitian menunjukkan bahwa tidak terdapat interaksi yang nyata antara kedua faktor tersebut, dan komposisi media tanam tidak memberikan pengaruh nyata terhadap semua parameter yang diamati. Sebaliknya, lama pengomposan memberikan pengaruh nyata hingga sangat nyata terhadap tinggi tanaman, jumlah daun, lebar tajuk, bobot segar, dan hasil per unit percobaan. Perlakuan lama pengomposan 42 hari menghasilkan bobot segar tertinggi (72,05 g) dan hasil per unit percobaan sebesar 215,83 g. Kesimpulannya, lama pengomposan memainkan peran yang lebih penting daripada komposisi media tanam. Periode *pengomposan yang lebih lama menghasilkan kompos yang lebih matang dan meningkatkan ketersediaan unsur hara, sehingga meningkatkan pertumbuhan dan hasil selada merah.*

ABSTRACT
This study aimed to determine the interaction and effects of growing media composition and composting duration of Australian pine (Casuarina equisetifolia L.) leaf waste on the growth and yield of red lettuce (Lactuca sativa L. var. Red Rapid), as well as to evaluate the potential use of Australian pine leaf waste as an alternative compost material. The experiment was arranged in a factorial Randomized Complete Block Design (RCBD) with two factors: growing media composition (K0 = 2:1:0, K1 = 2:1:1, K2 = 2:1:2, and K3 = 2:1:3) and composting duration (L1 = 14 days, L2 = 28 days, and L3 = 42 days). A total of 12 treatment combinations were replicated three times, resulting in 36 experimental units. The results showed that there was no significant interaction between the two factors, and the growing media composition had no significant effect on any of the observed parameters. In contrast, composting duration had significant to highly significant effects on plant height, number of leaves, canopy width, fresh weight, and yield per experimental unit. The 42-day composting treatment produced the highest fresh weight (72.05 g) and yield per experimental unit (215.83 g). In conclusion, composting duration played a more important role than growing media composition. A longer composting period produced more mature compost with greater nutrient availability, thereby enhancing the growth and yield of red lettuce.

INTRODUCTION

Indonesia is one of the countries with a continuously increasing population growth rate from year to year. This increase in population has a direct impact on food demand, particularly vegetables as a source of vitamins and minerals for the community. Among various horticultural commodities, red lettuce (Lactuca sativa L. var. Red Rapid) has high economic value and steadily increasing demand, both in traditional markets, supermarkets, restaurants, and hotels, especially in urban areas (Pratama et al., 2024). This leafy vegetable is very popular due to its crispy texture and high nutritional content (Kim et al., 2016). However, national lettuce production remains relatively low. Data from the Ministry of Agriculture (2023) indicate that the average production of red lettuce in Indonesia has only reached 12.5 tons/hectare over the past five years, far below countries such as the United States and the Netherlands, which can produce more than 20 ton ha-1 (FAO, 2022). This low productivity is partly attributed to the suboptimal use of growing media and fertilizers, making innovation in plant nutrient provision highly urgent.

Similar problems also occur in Bengkulu Province, where lettuce cultivation is generally still carried out on a medium-scale farming basis or local hydroponic systems. Its production has not been recorded as an independent commodity and is still grouped under the category of other vegetables by the Central Bureau of Statistics (BPS Bengkulu Province, 2024). In fact, with Bengkulu's population projected to reach 2.09 million people in 2024, the need for a stable and high-quality supply of leafy vegetables is becoming increasingly urgent. On the other hand, Bengkulu Province has abundant potential of sea casuarina vegetation (Casuarina equisetifolia L.), especially along coastal areas such as the Air Rami 1 Nature Reserve, Seblat Nature Reserve, and the Pantai Panjang and Pulau Baai Nature Tourism Parks, with individual density reaching 60–67 trees per hectare (Farma et al., 2019). This abundance produces very high amounts of casuarina leaf litter waste, yet its utilization as raw material for organic fertilizer in agrotechnology remains very limited. In fact, casuarina leaves contain lignin and cellulose that can decompose into compost rich in macro and micro nutrients such as nitrogen (N), phosphorus (P), and potassium (K) (Sutanto, 2019; Hidayat et al., 2020).

To improve the quality of casuarina leaf compost, efforts to accelerate decomposition are necessary considering that high lignin content causes composting time to reach 30–60 days (Adani et al., 2007). One potential strategy is to mix pineapple peel waste (Ananas comosus). Pineapple peel waste is abundantly available from fruit and juice vendors, and if not managed properly, it will cause environmental pollution. Pineapple peels contain K (1.137%), P (63 mg/100 grams), and N levels of up to 1.82% after fermentation with a bioactivator (Nasution et al., 2014; Nasrun et al., 2016). The use of a mixture of pineapple peels with casuarina leaf litter is specifically intended to increase the nutrient content of organic fertilizer while accelerating the decomposition process of organic matter into ready-to-use nutrients. However, to date, it is not known exactly what the optimal composting duration is for the mixture of casuarina leaves and pineapple peels, nor how different composting durations affect the growth and yield of red lettuce plants.

Based on the background description above, it is evident that although the potential of casuarina leaf and pineapple peel waste in Bengkulu Province is very abundant, scientific information regarding the optimal composting duration of the mixture of these two organic materials and their impact on compost quality and plant growth is not yet available. Therefore, the main problems to be answered in this study are whether different composting durations have a significant effect on the physical and chemical quality of the compost mixture of casuarina leaves and pineapple peels, how the composting duration and the application of this compost affect the growth and yield of red lettuce plants, and what the optimal composting duration is to produce the best compost for red lettuce cultivation in Bengkulu Province. In line with these problems, this study generally aims to analyze the effect of composting duration of a mixture of casuarina leaves (Casuarina equisetifolia) and pineapple peels (Ananas comosus) on the quality characteristics of the resulting compost, to test the growth and yield responses of red lettuce plants (Lactuca sativa L. var. Red Rapid) to the application of compost with different composting durations, and to determine the best composting duration capable of producing high-quality compost while optimally supporting the productivity of red lettuce. By achieving these objectives, this study is expected to provide technical recommendations for farmers and stakeholders in utilizing local waste to sustainably increase leafy vegetable production.

MATERIALS AND METHODS

This research was conducted at an experimental field located on Jalan Danau 14, Panorama, Bengkulu City, at an altitude of 24 m above sea level. The study took place from November 2024 to January 2025. Based on local climatological data, during the research period the average air temperature ranged from 26.5°C to 27.8°C, relative humidity ranged from 83% to 87%, and monthly rainfall ranged from 350 - 500 mm.

Experimental Design

A factorial Randomized Complete Block Design (RCBD) was employed with two factors. The first factor was growing medium composition, consisting of four levels: growing medium without casuarina leaf compost (soil:manure = 2:1); growing medium with casuarina leaf compost equivalent to one part (2:1:1); two parts (2:1:2); and three parts (2:1:3). The second factor was composting duration, consisting of three levels: 14 days, 28 days, and 42 days. The combination of the two factors resulted in 12 treatments, each replicated three times, giving a total of 36 experimental units. Each experimental unit contained five red lettuce plants of the Red Rapid variety, for a total of 180 plants. The data were analyzed using analysis of variance (ANOVA) at the 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Land and Growing Medium Preparation

The research began with land and growing medium preparation. The land was cleared of weeds and root residues. Polybags of 20 cm × 25 cm with a capacity of 5 kg of growing medium were filled with a mixture of soil, manure, and casuarina leaf compost according to the treatments. The soil used was local mineral soil, the manure was obtained from decomposed cow dung, while the casuarina leaf compost was obtained from composting processes of different durations. The polybags were arranged with a spacing of 20 cm × 20 cm.

Compost Preparation

Compost was prepared from a mixture of casuarina leaves and pineapple peels using 20 kg of chopped casuarina leaf litter (Casuarina equisetifolia L.), 10 kg of fresh pineapple peel waste, 90 mL of EM4 bioactivator, 90 g of dissolved brown sugar, and 10 L of water. The casuarina leaves and pineapple peels were mixed evenly, after which the EM4 and brown sugar solution was poured over the mixture. The composting process was carried out in 80 L drums, sealed tightly, and opened every three days for aeration. Regular checks were performed to monitor changes in color, odor, and texture of the compost. The process proceeded for 14, 28, or 42 days according to the treatment specifications. The resulting compost was air-dried.

Seedling Preparation and Planting

Red lettuce seedlings were raised using a seedling medium consisting of a mixture of soil, decomposed manure, and burnt husk (2:1:1). The seeds were soaked in warm water at 40–50°C for 30 minutes to break dormancy, then drained. The seeds were spread evenly over the seedling medium in trays, then covered with a thin layer of fine soil approximately 0.5 cm thick. The seedling medium was maintained at adequate moisture levels by watering in the morning and afternoon, and was shaded with 50%

paranet shade cloth. Seeds germinated at 3–5 days after sowing. Seedlings were transplanted into polybags at 14–21 days after sowing or when they had 4–5 leaves. Planting was carried out in the late afternoon. Each planting hole was filled with one seedling, the soil was gently compacted, and water was applied immediately. Silver-black plastic mulch was installed, along with 30% paranet shading if sunlight intensity was too high. Basal NPK 16:16:16 fertilizer was applied at 2 g per polybag and mixed evenly into the growing medium prior to planting.

Plant Maintenance

Maintenance activities included watering once or twice daily, replanting of dead seedlings up to 5 days after planting (DAP), and weeding every 1–2 weeks. Control of aphids (Myzus persicae) and leaf caterpillars (Plutella xylostella) was carried out using organic neem or garlic pesticides, while leaf blight disease (Sclerotinia spp.) was prevented through sanitation and air circulation.

Observed Variables

The observed parameters included plant height (cm), number of leaves (leaves), canopy width (cm), fresh weight per plant (g•plant^{-1}), and fresh weight per experimental unit (g•unit^{-1}). Plant height was measured weekly at 7, 14, 21, 28, and 35 DAP. The number of leaves was counted at the same intervals. Canopy width was measured at harvest. Fresh weight was weighed immediately after harvest using a digital balance. All data were analyzed statistically as described above.

RESULTS AND DISCUSSION

Based on the analysis of variance, the effects of casuarina leaf medium composition and composting duration on all observed parameters are presented in Table 1 below.

Table 1. The calculated F-values from the analysis of the treatments of casuarina leaf medium composition and composting duration on red lettuce plants are presented as follows.

Data Collection	F-value			CV %
	Composition	Composting Duration	Interaction	
Plant height at 7 DAP	0.67 ns	0.85 ns	1.82 ns	13.96
Plant height at 14 DAP	0.70 ns	1.65 ns	1.88 ns	6.40
Plant height at 21 DAP	1.16 ns	4.11 *	1.06 ns	10.28
Plant height at 28 DAP	0.65 ns	6.59 **	0.44 ns	13.79
Plant height at 35 DAP	0.32 ns	12.78 **	1.08 ns	11.72
Plant height at 42 DAP	0.80 ns	16.25 **	1.02 ns	19.11
Number of leaves at 7 DAP	0.33 ns	4.49 *	0.62 ns	16.18
Number of leaves at 14 DAP	0.35 ns	0.60 ns	0.18 ns	18.25
Number of leaves at 21 DAP	0.11 ns	13.57 **	1.71 ns	15.56
Number of leaves at 28 DAP	0.67 ns	21.32 **	2.02 ns	15.20
Number of leaves at 35 DAP	0.38 ns	0.51 ns	0.11 ns	13.09
Number of leaves at 42 DAP	1.63 ns	2.14 ns	0.31 ns	15.87
Plant canopy width	0.84 ns	15.38 **	1.22 ns	11.32
Weight per plant	0.70 ns	14.65 **	1.55 ns	17.33

Weight per experimental unit	0.69 ns	14.76 **	1.58 ns	13.31

Note : ns : not significant
* : significant
** : highly significant
CV : coefficient of variation

Based on the analysis of variance, the composting duration treatment showed varying effects on the growth and yield parameters of red lettuce plants. Composting duration had a non-significant effect on plant height at 7 and 14 days after planting (DAP), as well as on the number of leaves at 14, 35, and 42 DAP. However, composting duration had a significant effect on plant height at 21 DAP and on the number of leaves at 7 DAP. Highly significant effects of composting duration were observed on plant height at 28, 35, and 42 DAP, the number of leaves at 21 and 28 DAP, plant canopy width, post-harvest weight per plant, and weight per experimental unit. Meanwhile, the factor of casuarina leaf medium composition and the interaction between medium composition and composting duration indicated non-significant effects on all observed parameters, including plant height, number of leaves, plant canopy width, post-harvest weight per plant, and weight per experimental unit.

Plant height (cm)

Based on the results of the analysis, the composting duration treatment had a non-significant effect on plant height at 7 and 14 DAP. However, it had a significant effect on plant height at 21 DAP and a highly significant effect on plant height at 28, 35, and 42 DAP. Meanwhile, the casuarina leaf medium composition treatment and its interaction with composting duration had non-significant effects on plant height.

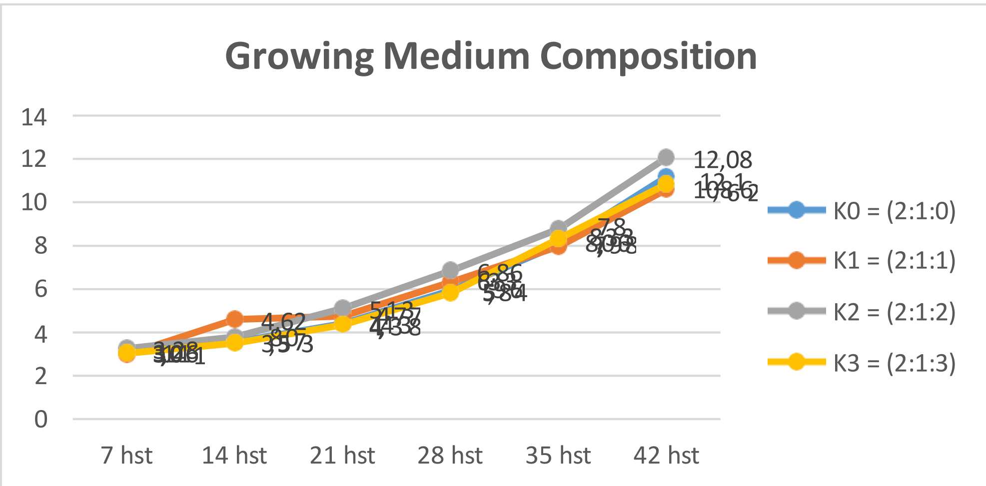

Fig 1. Mean Plant Height of Red Lettuce Plants as Affected by Casuarina Leaf Medium Composition

According to the Duncan's Multiple Range Test (DMRT), there were no significant differences among the casuarina leaf medium composition treatments for plant height at 7, 14, 21, 28, 35, and 42 DAP.

Table 2. Mean Plant Height of Red Lettuce Plants as Affected by Composting Duration

Composting Duration	Mean Analysis Results					
	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP
L1 = 14 day	2.99 a	3.41 a	4.08 b	4.86 b	6.14 b	8.50 c
L2 = 28 day	3.21 a	4.57 a	4.75 ab	6.54 a	8.80 a	11.66 b
L3 = 42 day	3.15 a	3.66 a	5.20 a	7.34 a	9.93 a	13.42 a

Note: Means followed by the same letter within the same column are not significantly different based on DMRT at α = 0.05, no further test was conducted.

Based on the DMRT follow-up test for the composting duration treatment at 21 DAP, L1 (14 days) was not significantly different from L2 (28 days) but was significantly different from L3 (42 days). At 28 and 35 DAP, L1 (14 days) was significantly different from both L2 (28 days) and L3 (42 days); however, L2 (28 days) and L3 (42 days) were not significantly different from each other. At 42 DAP, L1 (14 days) was significantly different from L2 (28 days) and L3 (42 days), and L2 (28 days) was also significantly different from L3 (42 days). Leaf Number (leaves)

Based on the results of the analysis, the composting duration treatment had a non-significant effect on the number of leaves at 14, 35, and 42 DAP. However, it had a significant effect on the number of leaves at 7 DAP and a highly significant effect on the number of leaves at 21 and 28 DAP. Meanwhile, the casuarina leaf medium composition treatment and its interaction had non-significant effects on the number of leaves parameter.

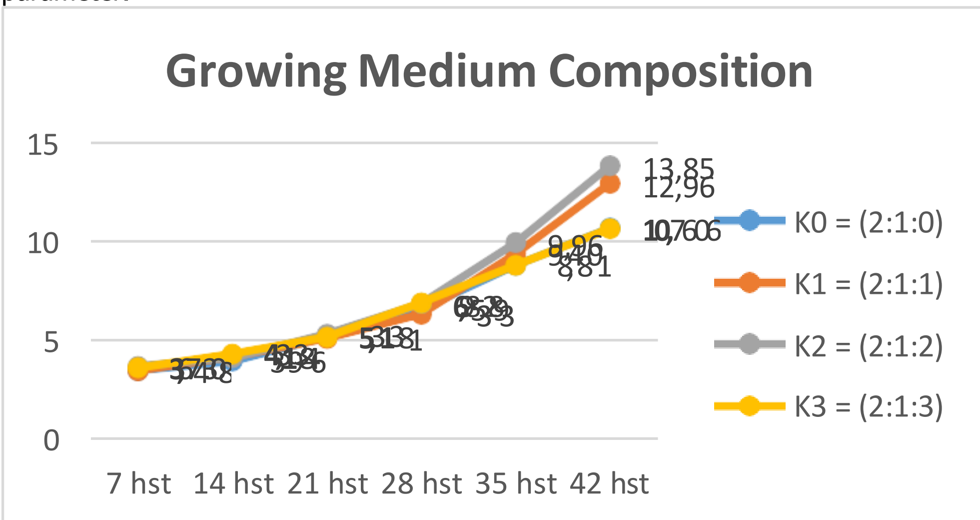

Fig 2. Mean Leaf Number of Red Lettuce Plants as Affected by Casuarina Leaf Medium Composition

The casuarina leaf medium composition treatments showed no significant differences among each other at all observation periods (7, 14, 21, 28, 35, and 42 DAP).

Table 4. Mean Leaf Number of Red Lettuce Plants as Affected by Composting Duration

Composting Duration	Mean Analysis Results					
	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP
L1 = 14 day	3.16 b	4.19 a	4.22 b	5.13 b	8.86 a	10.36 a
L2 = 28 day	3.77 a	3.97 a	5.55 a	7.25 a	9.08 a	12.25 a
L3 = 42 day	3.77 a	4.30 a	5.83 a	7.66 a	9.80 a	13.52 a

Note: Means followed by the same letter within the same column are not significantly different based on DMRT at α = 0.05, no further test was conducted.

Based on the DMRT follow-up test for the number of leaves at 21 and 28 DAP, the composting duration treatment L1 (14 days) showed significant differences compared to L2 (28 days) and L3 (42 days). Conversely, L2 (28 days) and L3 (42 days) also differed significantly from L1 (14 days).

Plant Canopy Width (cm)

Based on the results of the analysis, the composting duration treatment had a highly significant effect on plant canopy width. However, the casuarina leaf medium composition treatment and its interaction had non-significant effects on post-harvest weight per plant

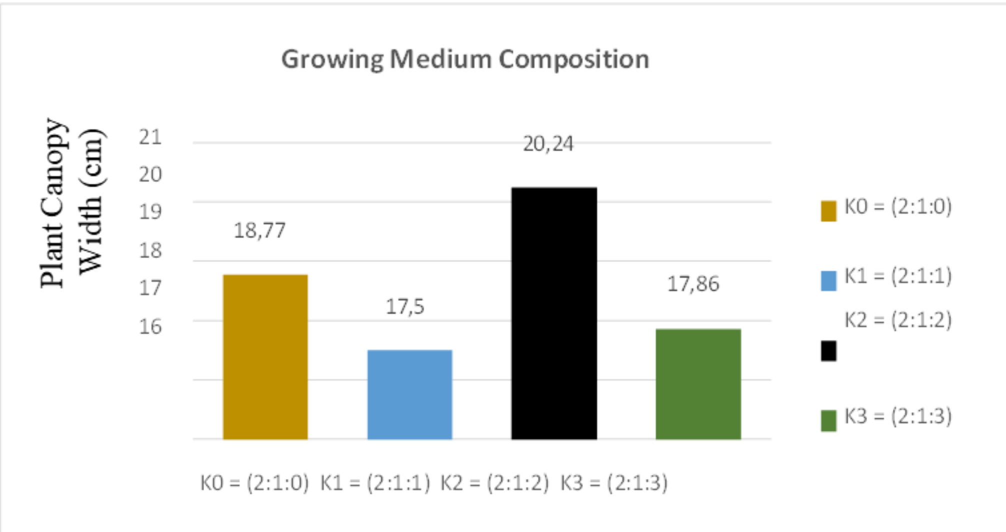

Fig 3. Mean Canopy Width of Red Lettuce Plants as Affected by Casuarina Leaf Medium Composition

Based on the Duncan's Multiple Range Test (DMRT), there were no significant differences among the casuarina leaf medium composition treatments at all observation periods (7, 14, 21, 28, 35, and 42 DAP).

Table 5. Mean Canopy Width of Red Lettuce Plants as Affected by Composting Duration

Composting Duration	Mean Analysis
Results L1 = 14 day	13.65 b
L2 = 28 day	19.61 a
L3 = 42 day	22.52 a

Note: Means followed by the same letter within the same column are not significantly different based on DMRT at α = 0.05, no further test was conducted

Based on the Duncan's Multiple Range Test (DMRT), the composting duration treatment L1 (14 days) showed significant differences in plant canopy width compared to L2 (28 days) and L3 (42 days). Conversely, L2 (28 days) and L3 (42 days) also differed significantly from L1 (14 days).

Plant Weight (g)

Based on the analysis of variance, composting duration significantly affected post-harvest weight per plant. In contrast, casuarina leaf medium composition and its interaction with composting duration showed no significant effects on post-harvest weight per plant.

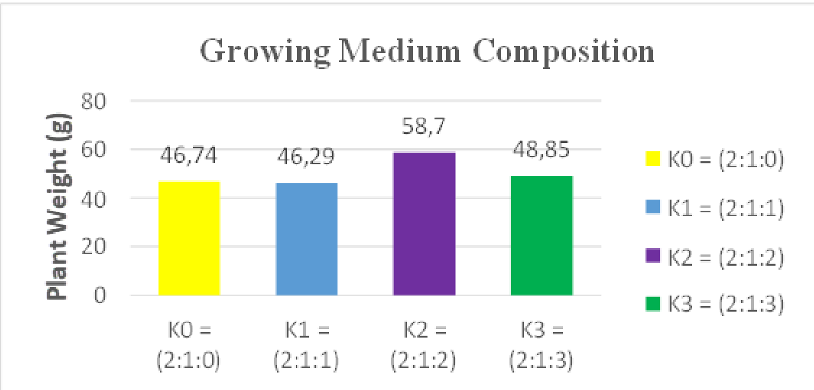

Fig 4. Mean Plant Weight of Red Lettuce Plants as Affected by Casuarina Leaf Medium Composition

Based on the Duncan's Multiple Range Test (DMRT), there were no significant differences among the casuarina leaf medium composition treatments at all observation periods (7, 14, 21, 28, 35, and 42 DAP).

Table 6. Mean Plant Weight of Red Lettuce Plants as Affected by Composting Duration

Composting Duration	Mean Analysis
Results L1 = 14 day	22.27 b
L2 = 28 day	56.11 a
L3 = 42 day	72.05 a

Note: Means followed by the same letter within the same column are not significantly different based on DMRT at α = 0.05, no further test was conducted

Based on the DMRT follow-up test, the composting duration treatment L1 (14 days) was significantly different from L2 (28 days) and L3 (42 days). Likewise, L2 (28 days) and L3 (42 days) were significantly different from L1 (14 days).

Weight per Experimental Plot (g)

Based on the analysis of variance, composting duration significantly affected weight per experimental unit. In contrast, casuarina leaf medium composition and its interaction with composting duration showed no significant effects on weight per experimental unit.

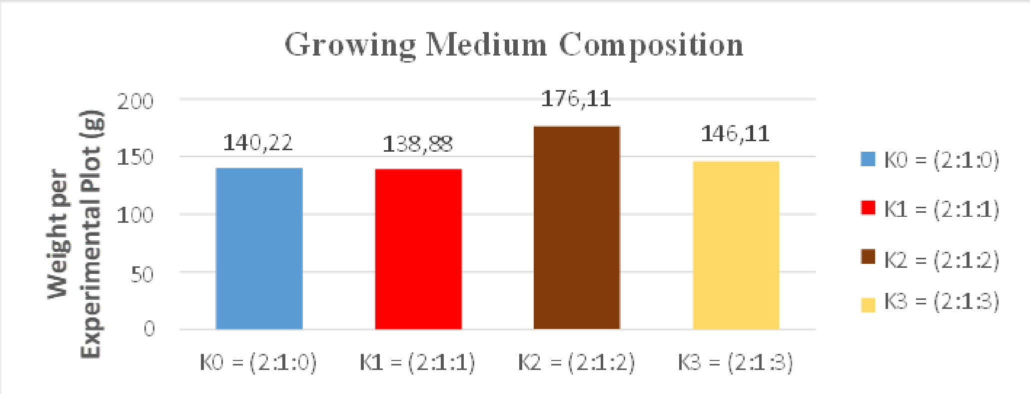

Fig 5. Mean Weight per Experimental Unit of Red Lettuce Plants as Affected by Casuarina Leaf Medium Composition

Based on the Duncan's Multiple Range Test (DMRT), there were no significant differences among the casuarina leaf medium composition treatments at all observation periods (7, 14, 21, 28, 35, and 42 DAP).

Table 7. Mean Weight per Experimental Unit of Red Lettuce Plants as Affected by Composting Duration.

Composting Duration	Mean Analysis
Results L1 = 14 day	66.83 b
L2 = 28 day	168.33 a
L3 = 42 day	215.83 a

Note: Means followed by the same letter within the same column are not significantly different based on DMRT at α = 0.05, no further test was conducted

Based on Duncan's Multiple Range Test (DMRT), the composting duration treatment L1 (14 days) differed significantly from both L2 (28 days) and L3 (42 days).

The results showed that the interaction between medium composition and composting duration of sea casuarina leaves (Casuarina equisetifolia L.) had no significant effect on all growth and yield parameters of red lettuce plants (Lactuca sativa L. var. Red Rapid). The highest interaction values were observed for plant height at 14 DAP (1.82) and 7 DAP (1.81), while the lowest was observed for the number of leaves at 35 DAP (0.17). This condition indicates that the combinations of organic matter proportions and decomposition durations tested were not able to create a sufficiently strong synergy to significantly alter the plant's physiological responses. The absence of a significant interaction is thought to be due to the characteristics of casuarina leaves, which have very high lignin and cellulose content (25-30%), so the decomposition process of organic matter proceeds very slowly even though the composting duration has been extended. According to Lailatul (2024), the effectiveness of compost as a growing medium strongly depends on its maturity level; if the organic matter has a high lignin content, nutrient mineralization will proceed slowly and uniformly across different composition levels. Zazkia (2025) explains that in the early to maturation phases, the stability of organic matter is more determined by the activity of decomposer microbes than merely the proportion of medium volume, which explains why the independent factor of composting duration was more dominant than its interaction with medium composition. This is consistent with Arifin et al. (2021), who stated that the limited availability of readily available nutrients in woody litter compost often results in insignificant plant responses when applied within a short cultivation period such as for lettuce.

The independent factor of casuarina leaf medium composition had no significant effect on all growth and yield parameters of red lettuce plants, both in the vegetative phase and at harvest. This indicates that differences in the proportion of casuarina leaf compost volume in the growing medium (K1 2:1:1, K2 2:1:2, and K3 2:1:3) were not able to create sufficiently significant changes in the physical and chemical properties of the medium to differentiate plant growth responses compared to the control (K0). The absence of a significant effect is thought to be due to the characteristics of casuarina leaves, which have high lignin and cellulose content (30-40%), so the mineralization or nutrient release process proceeds very slowly. Because red lettuce has a short life cycle (35-42 DAP), the nutrient availability from different medium compositions did not have time to produce contrasting effects on fresh weight or leaf number. Arifin et al. (2021) explained that the addition of organic matter with similar characteristics often results in uniform porosity stability and water-holding capacity in the growing medium. Wibowo et al. (2024) emphasized that the effectiveness of organic growing media strongly depends on the availability of ready-to-absorb nitrogen; if the decomposition process has not reached the optimal point to break carbon-lignin bonds, increasing the medium dosage will not provide meaningful additional nutrients. Febriyono and Rahmah (2021) stated that in media with a relatively high C/N ratio, microorganisms tend to immobilize nitrogen for their own decomposition activities rather than supplying it to plant roots.

The independent factor of composting duration had a significant effect on the growth and yield of red lettuce plants, where longer composting durations (L3: 42 days and L2: 28 days) tended to produce better growth compared to the shorter duration (L1: 14 days). This indicates that sufficient decomposition time is crucial for breaking down the recalcitrant organic material of casuarina leaves into nutrients available to plants. The longer the composting process takes place, the lower the C/N ratio in the medium will become toward a stable point, so that competition for nitrogen between decomposer microorganisms and plant roots can be minimized. In addition, an adequate composting duration allows for the degradation of inhibitory compounds such as tannins or phenols often found in casuarina leaves. Widarti et al. (2015) explained that composting duration strongly determines the maturity level of compost; the longer the composting time, the finer the texture of the organic matter and the more significantly nutrient mineralization (especially N, P, and K) will increase. Isroi (2008) added that mature compost is characterized by a decrease in the C/N ratio to below 20, which is a primary requirement for optimal nutrient absorption. Hahuly et al. (2022) stated that optimal decomposition duration plays an important role in increasing the cation exchange capacity (CEC) of the growing medium.

Composting duration treatment had no significant effect on plant height at 7 and 14 DAP because the early growth phase of the plant still depends on energy reserves from the seed and the growing medium that has not yet fully provided nutrients. At 21 DAP, the effect began to appear significant, and at 28, 35, and 42 DAP it became highly significant, indicating that the effect of compost application on plant height only became clearly apparent in the late vegetative phase as plant nutrient requirements increase and nutrient stability from the compost itself improves. A similar pattern was observed for the number of leaves parameter, where composting duration treatment had no significant effect at 14, 35, and 42 DAP, but had a significant effect at 7 DAP and a highly significant effect at 21 and 28 DAP. These varying responses indicate that in the early and mid-vegetative phases, differences in composting duration can significantly affect leaf growth expression, but these effects cannot be maintained until the pre-harvest phase. Laužikė (2025) supports these findings, where compost application significantly increased the number of lettuce leaves due to improved nutrient availability and improved physical-chemical properties of the medium. The medium composition treatment and its interaction showed no significant effect on post-harvest weight, indicating that the number of leaves as a vegetative parameter does not always correlate directly with final harvest weight, considering that other physiological factors such as photosynthetic efficiency and biomass allocation also play a role.

Composting duration treatment had a highly significant effect on the canopy width of red lettuce plants, indicating that variations in composting duration were able to modify the conditions and nutrient availability in the medium, thereby affecting vegetative expansion of the plant. In contrast, the medium composition treatment and its interaction had no significant effect on post-harvest plant weight, indicating that increased canopy width was not always followed by increased harvest weight. Marutani and Clemente (2021) showed that the quality of compost-based growing media significantly affects vegetative growth aspects such as canopy width through improved nutrient availability and improved physical properties of the medium.

Composting duration treatment also showed a significant effect on post-harvest weight, indicating that decomposition duration is a primary determining factor for the maturity level of organic matter and nutrient availability. Sufficient composting time will optimally lower the C/N ratio, neutralize phytotoxic compounds, and facilitate mineralization so that macro-nutrients become available to the root system. Conversely, insufficient composting time results in immature compost, triggering nitrogen immobilization by microorganisms that is detrimental to plants. Pangestuti et al. (2021) stated that optimal composting duration is positively correlated with increased nutrient availability in the soil, which directly drives biomass formation. The casuarina leaf medium composition treatment had no significant effect on post-harvest weight because of the recalcitrant nature of casuarina leaves, so variations in dosage were not able to contribute significant nutrients, but rather only functioned as an amendment for the physical properties of the medium. When converted to a large-scale land area, the red lettuce production results in this study are still relatively low (not yet reaching ≥12 tons/ha under ideal conditions), strongly suspected to be due to the incomplete composting process of casuarina leaves. Handayani and Purnomo (2022) stated that litter with high lignin content such as casuarina leaves has a slow mineralization rate and has the potential to exert partial allelopathic effects in the early phase.

The weight per experimental unit parameter showed a similar pattern to harvest weight. Longer decomposition processes ensure the creation of an optimal root environment through the formation of humus compounds, resulting in higher weight per experimental unit. Prasetyo et al. (2022) stated that the stability of organic matter in fully mature compost increases the absorption efficiency of N, P, and K. The non-significant effect of casuarina leaf composition is due to the high C/N ratio and lignin content that requires a much longer decomposition time than the life cycle of annual plants. According to Hidayat and Saputro (2021), organic residues with complex cellulose structures tend to have slow mineralization rates, thus often having non-significant effects on plant fresh weight in the first planting period. The best medium composition in this study tended to be shown by the K1 treatment (2:1:1), although statistically it was not significantly different. Agronomically, this composition is considered more balanced because it is able to provide sufficient proportions of organic matter and base medium to maintain aeration, drainage, and water-holding capacity without causing an excess of incompletely decomposed organic matter. Arifin et al. (2021) stated that a balanced composition of growing medium between organic and inorganic materials is very important for maintaining the physical stability of the medium. Thus, the low yield per hectare in this study was more influenced by the suboptimal maturity of casuarina leaf compost rather than solely by the growing medium composition.

CONCLUSIONS

Based on the study "Effect of Growing Medium Composition and Composting Duration of Sea Casuarina Leaf Waste on Red Lettuce (Lactuca sativa L. var. Red Rapid)", the interaction between growing medium composition and composting duration had no significant effect on all growth and yield parameters. The medium composition treatment had no significant effect on plant height, number of leaves, canopy width, or fresh weight. However, the composting duration treatment significantly affected plant height, leaf number, canopy width, fresh weight, and yield per experimental unit during the vegetative phase (21–42 DAP).

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