



Growth Response of Mung Bean (*Vigna radiata* L.) to Biochar and Liquid Organic Fertilizer from *Samanea saman* (Jacq.) Merr Leaves Combined with Bone Meal

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Abstract: The limited phosphorus content in liquid organic fertilizer derived from *Samanea saman* (Jacq.) Merr. leaves may constrain its effectiveness in promoting the growth of mung bean (*Vigna radiata* L.). This study aimed to improve the fertilizer's efficacy by incorporating bone meal as a phosphorus source and applying biochar to enhance nutrient retention and soil properties. A 2×5 factorial experiment was arranged in a Completely Randomized Design (CRD), with two treatment factors: biochar application (0 and 100 g per polybag) and fertilizer formulations (control, 100% *S. saman* leaf extract, and combinations of *S. saman* leaf extract with bone meal at 25%, 50%, and 75% ratios). Growth parameters observed included plant height, number of leaves, and dry weight. The combination of 50% *S. saman* leaf fertilizer and 50% bone meal, supplemented with biochar, produced the highest performance, with a plant height of 65.72 cm, 22.06 leaves per plant, and a dry weight of 75.82 g. In contrast, treatments without biochar exhibited significantly lower growth. These findings demonstrate that the synergistic application of bone meal and biochar can substantially enhance nutrient availability and improve the performance of organic fertilizers in supporting mung bean growth.

Keywords: Biochar; Bone meal; Mung bean; *Samanea saman*

Introduction

Mung bean (*Vigna radiata* L.) is a widely cultivated food crop in Indonesia, valued for its high protein content, which makes it a vital source of plant-based nutrition in local dietary patterns (Fitriani & Taryono, 2022; Nurjanah et al., (2020). Despite its significance, current levels of mung bean production remain insufficient to meet the increasing market demand.

A major constraint contributing to the suboptimal yield is the decline in soil fertility. The prolonged and excessive application of inorganic fertilizers has further aggravated this issue, leading not only to the deterioration of soil structure but also to increased risks of environmental contamination. In response, the

utilization of organic fertilizers has emerged as a sustainable alternative to restore soil health and improve crop productivity. Liquid organic fertilizers (LOF) derived from biological materials have been reported to enhance soil fertility and promote plant growth (Guo et al. 2022; Liu et al. 2023).

Samanea saman (Jacq.) Merr. leaves represent an abundant local organic resource that remains underexploited in agricultural practices. Chemical analyses have shown that these leaves contain 6.25% nitrogen, 0.47% phosphorus, and 2.25% potassium (Utomo & Purwanti, 2023). Furthermore, essential micronutrients such as calcium and iron are also present in appreciable amounts (Akani et al., 2025). Although *S. saman* leaves are rich in both macro and micronutrients,

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their phosphorus content is relatively low, despite the fact that phosphorus is an essential nutrient for root development and seed formation. The incorporation of fish bone meal, which contains up to 17% phosphorus by dry weight (Darwish et al., 2020; Apriliani et al., 2025), has been demonstrated to effectively enhance mung bean yields (Samim et al., 2024; Ariani et al., 2025), thus serving as a viable phosphorus supplement.

Another constraint in the use of liquid organic fertilizer is the low nutrient uptake efficiency. Biochar can be used to increase nutrient retention and availability in the soil (Wang et al., 2024). It is the result of biomass pyrolysis and is stable, carbon-rich and porous. These characteristics support soil microbial activity and increase nitrogen and phosphorus availability (Elkhalifa et al. 2022; Xu et al. 2023; Premalatha et al. 2023). The combination of *S. saman* leaves, bone meal, and biochar application holds significant potential to enhance the efficacy of organic fertilizers and promote the sustainable growth of mung bean plants.

Method

This experimental study employed a Completely Randomized Design (CRD) with two factors: fertilizer formulation and biochar application. The first factor, fertilizer formulation, consisted of five levels: P0 (control), P1 (100% *Samanea saman*), P2 (75% *S. saman* + 25% bone meal), P3 (50% *S. saman* + 50% bone meal), and P4 (25% *S. saman* + 75% bone meal). The second factor was biochar application, comprising two levels: B0 (without biochar) and B1 (with biochar). Each treatment was replicated three times.

The experiment was conducted in Banda Aceh from March to May 2025. The liquid organic fertilizer was produced through anaerobic fermentation of *S. saman* leaves using EM4 and molasses for a duration of 21 days. Fish bone meal was prepared by boiling, drying, and grinding fish bones into powder form. Biochar was produced from coconut husk and rice husk via pyrolysis at temperatures ranging from 350 to 500°C. Mung bean

(*Vigna radiata* L.) seeds were sown in polybags containing the treated soil and cultivated for approximately 70 days under controlled conditions. The measured parameters included plant height, number of leaves, and dry weight. The data were analyzed using two-way analysis of variance (ANOVA), followed by a post hoc test (HSD) based on the threshold of the coefficient of variation (CV).

Result and Discussion

Plant Height

The ANOVA results showed a significant effect of the interaction between *Samanea saman*-based liquid organic fertilizer (LOF), fish bone meal, and biochar application on plant height (Table 1). The highest plant height was recorded in treatment B1P3, which consisted of 50% *S. saman* and 50% fish bone meal with biochar, reaching an average of 65.72 cm. In contrast, the lowest average plant height (33.78 cm) was observed in the control treatment without biochar (B0P0). Within each biochar treatment group, plant height increased gradually from the P0 (control) to the P3 level, suggesting that a balanced proportion of organic nitrogen from *S. saman* and phosphorus from bone meal supported optimal vegetative growth (Amin et al., 2024). The 50:50 ratio may have provided a favorable nutrient balance during early development, enhancing plant vigor and elongation. However, plant height declined in the treatment B0P4 (25% *S. saman* + 75% bone meal without biochar), indicating that further increasing the proportion of bone meal did not improve plant growth. This decline may be attributed to nutrient imbalance, as excessive phosphorus can disrupt nitrogen assimilation and limit vegetative development. These findings are consistent with previous studies showing that optimal growth is achieved not by maximizing a single nutrient but by maintaining a proper nutrient ratio. The addition of biochar likely enhanced nutrient retention and uptake, further contributing to increased plant height (Liao et al. 2022; Xu et al. 2023).

Table 1. Plant Height of Mung Bean after Treatment with LOF Formulation and Biochar

| Biochar | <i>S. saman</i> LOF and Bone Meal | | | | | x̄ |
|---------|-----------------------------------|---------------------|---------------------|--------------------|---------------------|-------|
| | P0 | P1 | P2 | P3 | P4 | |
| B0 | 33.78 ^d | 43.24 ^{cd} | 53.84 ^{bc} | 64.81 ^a | 63.01 ^{ab} | 51.14 |
| B1 | 37.28 ^d | 47.12 ^{cd} | 56.47 ^b | 65.72 ^a | 63.98 ^a | 54.11 |
| x̄ | 35.53 | 45.18 | 55.16 | 65.27 | 63.50 | |

Description: Numbers followed by the same letter indicate no significant difference based on the HSD test at a 95% significance level (α = 5%)

The findings indicate that the nutritional balance of the fertilizer plays a crucial role in determining plant growth. The P3 treatment, which provided a balanced

composition, was particularly advantageous due to the simultaneous availability of quickly soluble nutrients from organic matter and the gradual release of minerals from bone meal. Organic materials such as *S. saman*

leaves tend to decompose more rapidly, making macronutrients like nitrogen, phosphorus, and potassium available during the early growth stages. In contrast, mineral elements contained in bone meal, especially phosphorus and calcium, are released more slowly and contribute to sustained nutrient availability over time (Chen, 2016; Arista et al., 2015). According to Utomo et al. (2023), *S. saman* leaves contain a high nitrogen content, which is essential for chlorophyll formation and protein synthesis required for cell elongation. On the other hand, bone meal is a significant source of phosphorus and calcium, which are important for meristematic cell formation and root development (Kawasaki et al., 2024). An imbalance in nutrient ratios can negatively affect plant growth. Yang et al. (2024) reported that a disproportionate nitrogen-to-phosphorus ratio can significantly reduce plant biomass accumulation.

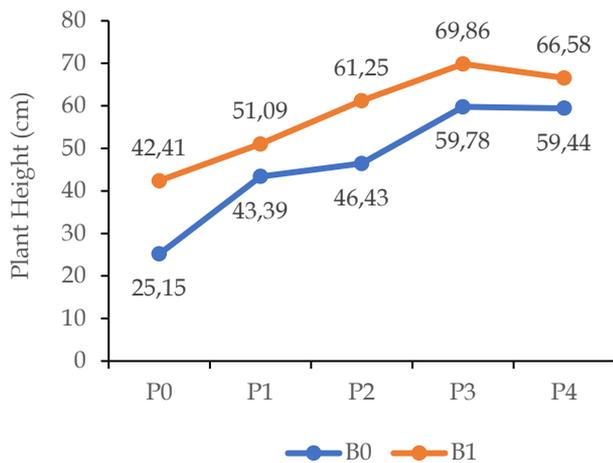


Figure 1. Plant height of mung bean under different fertilizer treatments with (B1) and without (B0) biochar

Figure 1. illustrates the effect of different fertilizer formulations (P0–P4) combined with and without biochar (B0 and B1) on the plant height of mung bean

(*Vigna radiata* L.). Across all fertilizer treatments, the addition of biochar (B1) consistently resulted in taller plants compared to those without biochar (B0), with the highest plant height observed in the P3B1 treatment (50% *S. saman* leaf fertilizer + 50% bone meal + biochar).

The observed increase in plant height following biochar application can be attributed to its beneficial effects on soil physical and chemical properties. Biochar improves soil structure by increasing porosity and reducing bulk density, which facilitates better root penetration and enhances the absorption of water and nutrients (Liu et al., 2023; Herath et al., 2013). Additionally, biochar contains essential cations such as potassium, calcium, and magnesium, which are crucial for enzymatic activity, osmotic balance, and overall plant metabolism (Jien & Wang, 2013; Lingga & Marsono, 2008). Enhanced potassium availability may also result from increased activity of potassium-solubilizing microorganisms stimulated by the presence of biochar (Ma et al., 2023; Kurniastuti & Faustina, 2019). The synergy between improved root access and nutrient availability contributes significantly to the vertical growth of mung bean plants.

Number of Leaves

The ANOVA results show a significant effect of the interaction between liquid organic fertilizer (LOF) formulation and biochar on the number of mung bean leaves (Table 2). The B1P3 treatment, which combined 50% *S. saman* leaves and 50% bone meal with biochar, produced the highest number of leaves (22.06). The B0P0 treatment (control, without biochar) resulted in the lowest number (19.78). In both biochar levels, the number of leaves increased from P0 to P3, followed by a slight decline at P4. This shows that increasing the proportion of bone meal up to 50% supported vegetative development, but excessive amounts (75%) reduced leaf formation. The improved leaf number at P3 indicates a balanced nutrient supply that optimally supports leaf growth.

Table 2. Number of leaves of Mung Bean after Treatment with LOF Formulation and Biochar

| Biochar | <i>S. saman</i> LOF and Bone Meal | | | | | \bar{x} |
|-----------|-----------------------------------|---------------------|---------------------|--------------------|----------------------|-----------|
| | P0 | P1 | P2 | P3 | P4 | |
| B0 | 19.78 ^c | 20.30 ^{bc} | 21.04 ^{ab} | 21.78 ^a | 20.66 ^{abc} | 20.71 |
| B1 | 20.12 ^c | 20.52 ^{bc} | 21.37 ^{ab} | 22.06 ^a | 21.12 ^{ab} | 21.04 |
| \bar{x} | 19.95 | 20.41 | 21.21 | 21.92 | 20.89 | |

Description: Numbers followed by the same letter indicate no significant difference based on the HSD test at a 95% significance level ($\alpha = 5\%$)

Nitrogen from *S. saman* leaves contributes to chlorophyll synthesis and stimulates the formation of new leaves (Utomo & Purwanti, 2023; Amri et al., 2018). Phosphorus from bone meal plays a role in energy metabolism and vascular development, while potassium

strengthens cell walls and supports leaf tissue structure (Kawasaki et al., 2024; Ando et al., 2020). A reduction in leaf number can limit photosynthesis and negatively affect plant productivity (Kasim et al., 2024; Fathnur et al., 2022). Nutrient imbalance, particularly in nitrogen

and phosphorus ratios, may also explain the lower leaf count at higher bone meal concentrations.

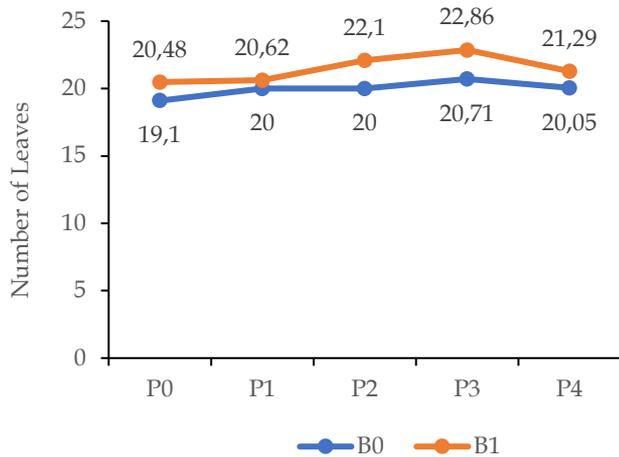


Figure 2. Number of leaves of mung bean under different fertilizer treatments with (B1) and without (B0) biochar

Figure 2. illustrates the number of leaves produced by mung bean plants under different fertilizer formulations, comparing treatments with (B1) and without (B0) biochar. The visual data suggest a

consistent positive response to biochar application. Further analysis showed that mung bean plants grown in media treated with biochar (B1) produced a higher average number of leaves compared to those grown without biochar (B0). Biochar application enhances nutrient retention and stabilizes nutrient availability in the rhizosphere through adsorption and gradual release mechanisms (Clough et al., 2013; Schmidt et al., 2015). Adequate potassium levels, derived from both biochar and organic matter, support stomatal regulation and leaf turgor pressure (Ma et al., 2023; Akhtar et al., 2002; Prawiranata et al., 1995; Wu et al., 2019). Under stable physiological conditions, cell division and leaf expansion can proceed more efficiently.

Dry Weight

The ANOVA results showed that the formulation of liquid organic fertilizer (LOF) based on *S. saman* leaves and bone meal, combined with biochar application, significantly increased the dry weight of mung bean plants. The B1P3 treatment, consisting of 50% *S. saman* leaves and 50% bone meal with biochar, produced the highest dry weight (22.06 g), while the control (B0P0) resulted in the lowest average dry weight (19.78 g).

Table 3. Dry Weight of Mung Bean after Treatment with LOF Formulation and Biochar

| Biochar | <i>S. saman</i> LOF and Bone Meal | | | | | \bar{x} |
|-----------|-----------------------------------|---------------------|---------------------|--------------------|---------------------|-----------|
| | P0 | P1 | P2 | P3 | P4 | |
| B0 | 33.78 ^d | 43.24 ^{cd} | 53.84 ^{bc} | 64.81 ^a | 63.01 ^{ab} | 51.14 |
| B1 | 37.28 ^d | 47.12 ^{cd} | 56.47 ^b | 65.72 ^a | 63.98 ^a | 54.11 |
| \bar{x} | 35.53 | 45.18 | 55.16 | 65.27 | 63.50 | |

Description: Numbers followed by the same letter indicate no significant difference based on the HSD test at a 95% significance level ($\alpha = 5\%$)

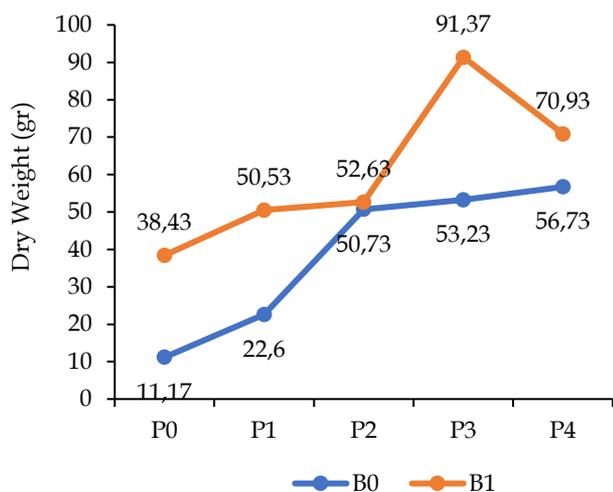


Figure 3. Dry weight of mung bean under different fertilizer treatments with (B1) and without (B0) biochar

In both biochar levels (B0 and B1), dry weight values increased from P0 to P3 and decreased at P4. This

improvement up to P3 can be attributed to the balanced nutrient supply, particularly nitrogen from *S. saman* leaves and phosphorus from bone meal. Nitrogen supports protein synthesis and the translocation of photosynthates into permanent tissues, while phosphorus and calcium contribute to root development, tissue strengthening, and energy transfer (Kawasaki et al., 2024; Aminah & Hersoelisyorini, 2019). The decrease at P4 suggests that an excessive proportion of bone meal may disturb nutrient balance and reduce nutrient use efficiency.

Figure 3. shows the dry weight of mung bean plants under different fertilizer formulations with (B1) and without (B0) biochar. Across both biochar levels, dry weight increased from P0 to P3 and then declined at P4. Further analysis indicated that biochar application (B1) consistently resulted in higher average dry weight across all fertilizer formulations compared to treatments without biochar (B0). Biochar enhances nutrient use efficiency due to its capacity to retain nutrients through

surface functional groups such as hydroxyl, carboxylate, and lactone, which bind nutrient ions and reduce leaching losses (Schmidt et al., 2015; Shamila et al., 2024; Sutrisno & Priyambada, 2019). Additionally, enzyme activities such as phosphatase are increased through interactions between biochar and plant roots (Ameloot et al., 2013; Fahri et al., 2022; Simanungkalit et al., 2006), thereby accelerating the mineralization of organic matter (Khairul et al., 2025; Aldin, 2021). These processes contribute to the development of a favorable rhizosphere environment that promotes biomolecule synthesis and supports improved plant growth (Jing et al., 2025; Jakunda et al., 2020).

Conclusion

Fertilizer formulation and biochar application significantly affected the growth of mung beans. The combined application of 50% *Samanea saman* leaf-based liquid organic fertilizer and 50% bone meal with biochar (B1P3) produced the highest values for plant height, number of leaves, and dry weight. These results indicate that a balanced nutrient composition and the presence of biochar improve nutrient availability and soil quality, leading to increased plant growth.

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Author Contributions

Conceptualization, T.M, H.R, M; methodology, T.M, and M; resources, T.M; writing original draft preparation, T.M, and H.R. All authors have read and agreed to published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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