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The Effect of White Lead Tree (*Leucaena leucocephala*) Leaves Compost and Biocon-NP on the Growth of Long Bean Plants (*Vigna sinensis* L.) in Lapindo Mud Media

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Abstract
Lapindo mud, which is abundantly available, requires improvement by adding organic materials and microbes to be used as planting media. The purpose of this study is to describe the impact of *Leucaena* leaves compost and Biocon-NP on the growth of long beans in Lapindo mud media. This experimental study employed a Randomised Group Design testing, two factors were tested that was *Leucaena* leaves compost (0 grams, 50 grams, and 100 grams) and Biocon-NP (0 ml, 125 ml, and 150 ml) with three replications. Vegetative parameters were identified, including plant height, number of leaves, root length, wet biomass, root nodule biomass, and active root nodule biomass. The observed generative parameters were age at first flower appearance, number of flowers, pods, and pod biomass. Two-way ANOVA was used to analyse the data, and then Duncan's test was performed. The outcome of the study indicated that the combination of 100 grams of *Leucaena* leaves compost and 150 ml Biocon- NP significantly increased plant height, wet biomass, root nodule biomass, active root nodule biomass, flowerage, number of flowers, number of pods, and pod biomass. Overall, our results demonstrate that the application of 150 ml of Biocon-NP in conjunction with 100 grams of *Leucaena* leaves compost increases the height of the plant, wet biomass, root nodule biomass, active root nodule biomass, age at first flower appearance, number of flowers, number of pods and pod biomass.

Keywords: *Leucaena* leaves compost; biocon-NP; lapindo mud; *Vigna sinensis* L.

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INTRODUCTION

Long bean (*Vigna sinensis* L.) is a perennial plant that grows vines (Ibrahim *et al.*, 2017), and is one of the vegetables widely used by Indonesian people in various dishes, both raw and cooked (Rizki *et al.*, 2015). Although the production of long beans has declined, the demand for long beans will continue to rise in tandem with the growth of the population. According to the data, long bean plant harvest has declined annually; in 2022, it amounted to 34,942, while in 2023, it was only 30,074 (Statistics Indonesia, 2023). Soekamto and Fahrizal (2019) claim that several factors are causing the decline of crop yields in Indonesia, including less intensive land use due to excess fertilizer use.

In Indonesia, there is a significant amount of marginal land or land with low agricultural productivity that can be used as a growing medium, one of which is Lapindo mud. Utilising Lapindo mud is necessary because hot mud continues to erupt to this day, and the volume of this mud eruption will only increase if it is not utilised. This eruption will cause a larger volume of Lapindo mud to pollute the surrounding environment. The development of Lapindo mud as planting media is one of the efforts to convert it into a more productive and environmentally friendly medium. The sample analysis by Yusuf (2022) indicates that the phosphate content of Lapindo mud is 3.75 ppm, and the nitrogen content is 0.04%. The nitrogen level, less than 0.1%, fell into the very low category. Because nitrogen is volatile, evaporation results in low nitrogen content (Umadi *et al.*, 2023). The availability of phosphate in Lapindo mud was classified as extremely low, at less than four parts per million. This is because at a pH greater than 7, phosphate will bind to form Ca-phosphate. Ca-phosphate, which is difficult to dissolve, can become available to plants thru dissolution processes and the formation of organic compounds by soil microbes (Sudrajat *et al*., 2014).

Chemical analysis of Lapindo mud reveals that the availability of nitrogen and phosphate is relatively low as a planting media mixture. In addition to its low nutrient content, the physical characteristics of Lapindo mud also pose challenges for plant growth. Clay deposits in Lapindo mud are physically grey in wet conditions and whitish grey in dry conditions (Winarno *et al*., 2019). Lapindo mud has a clayey, dusty, and sandy texture (Serdiani and Widiananta, 2019). According to Juniarwan *et al*. (2013), clay is the most significant component of Lapindo mud with the finest mud grains. The high clay content causes the micro pores to retain more water, increasing its water-holding capacity (Hanafiah, 2013). However, the clay composition also results in poor drainage and aeration, negatively affecting plant growth. Consequently, Lapindo mud generally has poor physical properties, a loose texture, and a low ability to retain air (Nasution *et al*., 2023).

Using Lapindo mud as a planting medium without additional supporting materials to improve soil texture and increase nutrient deficiencies can inhibit plant growth. The efficiency of marginal land use is still not optimally utilized by the community because its nutrient-poor and dry soil conditions cause the soil to be less fertile (Dwiastuti *et al.,* 2016). Therefore, treatment is needed to improve the quality of Lapindo mud media, which can be used effectively for agriculture. Through increasing chemical characteristics and boosting nutrient availability, adding organic materials like compost to planting media can improve soil fertility (Riskia *et al.,* 2024). One of the organic materials that can be used as the main ingredient in compost is *Leucaena* leaves. Based on the preliminary tests conducted in this study, *Leucaena* leaves compost contains 2.10% of N, 1.9% of P, and 1.57% of K. According to Sulham's research (2019), incorporating composted *Leucaena* leaves into the soil medium will enhance the physical characteristics of the soil, improve aeration and drainage, and increase the amount of nutrients that plants require.

To achieve a good yield, it is also necessary to apply fertilizers to boost high production yields and accelerate the plant growth process (Purba *et al.,* 2019). When biological fertilizer is applied to the soil, the existing microorganisms will multiply and play an active role in providing nutrients and enhancing plant productivity (Kartikawati *et al.,* 2017). One of the biological fertilizers that has many benefits because it contains microbes needed by plants is Biocon- NP biological fertilizer. Biocon-NP is a microbial inoculum that spurs plant growth, which includes a combination of bacteria such as, *Pseudomonas* sp., *Azotobacter* sp., and *Azospirillum* sp. *Azospirillum* sp and *Azotobacter* sp. are non-symbiotic nitrogen-fixing bacteria, while *Pseudomonas* is a phosphate-solubilizing bacteria. Nitrogen-fixing bacteria are able to fix the abundant nitrogen in the atmosphere so that N is available to plants, while phosphate-solubilizing bacteria are able to produce phosphatase enzymes and organic acids to dissolve phosphate bound by soil colloids so that it is available to plants (Umadi *et al.,* 2023).

Therefore, this study aims to examine the effect of *Leucaena* leaves compost and Biocon-NP on the growth and yield of long bean plants on Lapindo mud media. The treatment interaction is expected to improve soil fertility, increase nutrient availability, and maximize plant productivity on marginal land.

MATERIALS AND METHODS

This experimental study was conducted from November 2024 to January 2025 in Greenhouse C10, Biology Department of Surabaya State University. This study used a Randomized Group Design with two treatment factors: *Leucaena* leaves compost (0, 50, and 100 grams) and the concentration of Biocon-NP (0, 125, and 150 ml). The study consisted of 9 treatments with three replications, thus obtaining 27 sample units. The tools used in this study consisted of baskets, polybags, drums, soil pH meters, digital scales, rulers, sterile petri dishes, sterile pipettes, test tubes, incubators, LAFs, cameras, label paper, and stationery. Materials used include long bean seeds of the Kanton Tavi variety, *Leucaena* leaves, lapindo sludge, Biocon-NP inoculum, instant tiwul, yeast, Nutrient Agar (NA), distilled water, molasses, EM4, rice husks, and compost.

This research began with the preparation of *Leucaena* leaves compost obtained from the Lamongan plantation area, which was separated from the main stem, and air-dried for several days until its moisture content decreased. A total of 2 kg of dried leaves was finely chopped to accelerate the decomposition process, then mixed evenly with 1 kg of organic fertiliser and an EM4 solution made by mixing 10 mL of EM4 into 1 L of clean water. The mixture is placed in a compost bin with good air circulation. The bin is covered with burlap to maintain moisture and is stirred every 5 days to ensure aeration and accelerate microbial activity. If the compost appears dry, EM4 solution is added until it is moist. The composting process takes 4 weeks, and the compost is considered mature when it is dark brown in colour, crumbly in texture, and smells like soil.

The second stage is the production of Biocon-NP, testing the number of bacteria contained in Biocon-NP, and sterilising the fermentation drum. The yeast bread is boiled for 10 minutes, then placed into the fermentation drum with basic ingredients added, such as 500 grams of instant tiwul, 500 ml of molasses, 80 L of clean water, and stirred. Then, 50 grams of Biocon-NP inoculum was added, and the fermenter was turned on. Incubation was carried out for 4-5 days under cool and dry conditions. After incubation, a bacterial colony count test was performed on the liquid sample. The bacterial colony count test requires the preparation of a sterile diluent solution for serial aseptic dilution of the sample. Then, 1 mL of each dilution was poured into a sterile Petri dish, followed by the addition and even mixing of liquid PCA medium. Next, the dish is incubated inverted at 30 to 37°C for 24 to 48 hours in the subsequent step. Following incubation, a colony counter is used to count the number of growing bacterial colonies in a dish that contains 30 to 300 of these bacteria.

The third step in this process is preparing the soil medium. For this, the Lapindo mud, which will be combined as a planting medium, must first be dried, ground, and sieved. Each 35x35 cm polybag was filled with a ratio of 30% lapindo mud and 70% regosol soil in 5kg. Next, long bean seed that had been soaked and sown. Were transplanted into polybags after 5 days after sowing. The compost treatment was applied to the planting media one week before transplanting long bean seeds, and Biocon-NP was applied once every week starting from 1-week-old plants. Vegetative growth observation included the number of leaves, plant height, wet biomass, root length, root nodule biomass, and active root nodule biomass. The generative growth included age at first flower appearance, number of flowers, pods, and pod biomass.

The observations on the growth of long bean plants were analysed using SPSS 25, which included a normality test (Shapiro-Wilk), a homogeneity test, and then a two-way analysis of variance (Two-Way ANOVA). If there is an influence between groups, it is continued with a 5% Duncan test to determine differences in the interactions between groups. If the research data are abnormal and do not show significant results from the Two-Way ANOVA test, it is analysed descriptivel and quantitatively.

RESULTS

Testing the nutrient content of *Leucaena* leaves compost was conducted to determine the quality of compost that supports the growth of long bean plants on Lapindo mud media. The content of nutrients analysed includes organic carbon (C), nitrogen (N), C/N ratio, organic matter, phosphorus (P_2O_5), potassium (K_2O), and water content. The test results of the nutrient content in *Leucaena* leaves compost are presented in Table 1.

Table 1. Nutrient content of *Leucaena* leaves compost

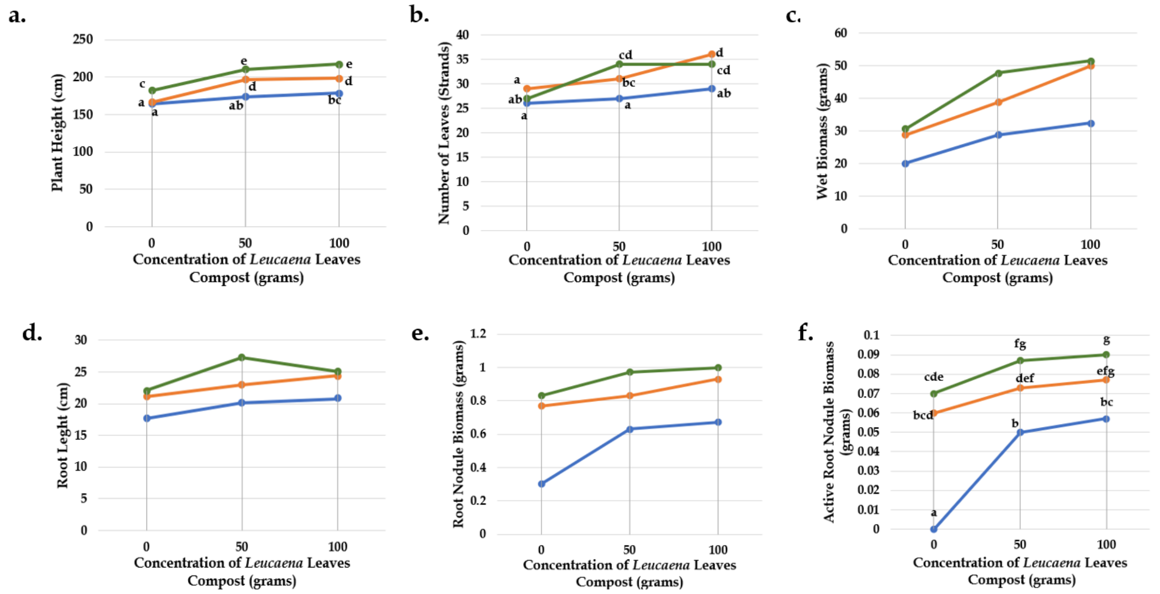
Parameter	Test Result	Quality Standard*
Organic Carbon (%C)	16,81	> 9,80 - < 32
Nitrogen (%N)	2,10	> 0,40
C/N Ratio	8,00	> 10 - < 20
Organic Matter (%)	28,91	> 27 - < 58
Total Phosphorus (%P_2O_5)	1,59	> 0,10
Total Potassium (%K_2O)	1,57	> 0,20
Water Content	47,70	< 50

Notes: *) Based on quality standard SNI 19-7030-2004

Based on the results in Table 1, the quality of *Leucaena* leaves compost meets most of the quality standards of SNI 19-7030-2004. The content of organic carbon, nitrogen, organic matter, phosphorus, potassium, and moisture content is in accordance with the quality standard. However, the C/N ratio of 8 is slightly below the quality standard of 10-20.

The bacterial content in Biocon-NP was analysed to determine the number of bacterial colonies present. Based on the calculation results, the total number of colonies contained in Biocon-NP biological fertiliser is 1.75×10^7 CFU/ml. This number has already met the minimum requirement of the quality standard for biological fertiliser in Permentan No. 70 of 2011, which is $\geq 10^7$ CFU/ml for the liquid form. It indicates that the bacterial population in Biocon-NP is within the range that can enhance plant growth.

The interaction between Biocon-NP and *Leucaena* leaves compost has a significant effect on plant height, leaf number, and active root nodule biomass parameters, but does not significantly affect biomass, root length, and root nodule biomass. The highest treatment was produced using 100 grams of *Leucaena* leaves compost and 150 ml Biocon-NP, with parameters including plant height, wet biomass, root nodule biomass, and active root nodule biomass. While a concentration of 100 grams of *Leucaena* leaves compost and 125 ml Biocon-NP effectively produced the most leaves. The concentration of 50 grams of *Leucaena* leaves compost and 150 ml Biocon-NP produced the highest root length.



Notes: : Biocon-NP 0 ml Biocon-NP 125 ml Biocon-NP 150 ml.

Figure 1. Effect of the combination of *Leucaena* leaves compost and Biocon-NP on a) plant height, b) number of leaves, c) wet biomass, d) root length, e) root nodule biomass, and f) active root nodule biomass (Different letters on the graph indicate significant effect based on Duncan test at 0.05 level).

The observations revealed that the generative phase in long bean plants begins before the completion of the vegetative phase, which typically lasts until 45 days after planting. Therefore, the study continued with observations of generative parameters, including flowerage, the number of flowers, the number of pods, and pod biomass. The results demonstrated that the three parameters were significantly impacted by the compost treatment of *Leucaena* leaves, Biocon-NP, and the combination of the two treatments (Figure 2).

DISCUSSION

According to the outcomes, the *Leucaena* leaves compost levels of organic carbon, nitrogen, organic matter, phosphorus, water content, and potassium have met the quality standard (Table 1). However, the C/N ratio of 8 falls just short of the 10–20 quality standard. Compost made from *Leucaena* leaves was able to boost the growth of long bean plants even though its quality was below the required level. The change in the compost material's C/N value is one indicator that shows how organic matter is breaking down during the composting process. Because carbon is used as an energy source and lost as CO_2, the C/N ratio changes during composting, decreasing carbon content (Pereira *et al.,* 2018). The C/N ratio, a measure of stability, will not change once the compost will reach maturity. The activity of decomposer microbes, however, affects the C/N ratio. It is known that CO_2 release causes the C value to drop while N remains constant, which lowers the ratio (Hanuf *et al.,* 2024).

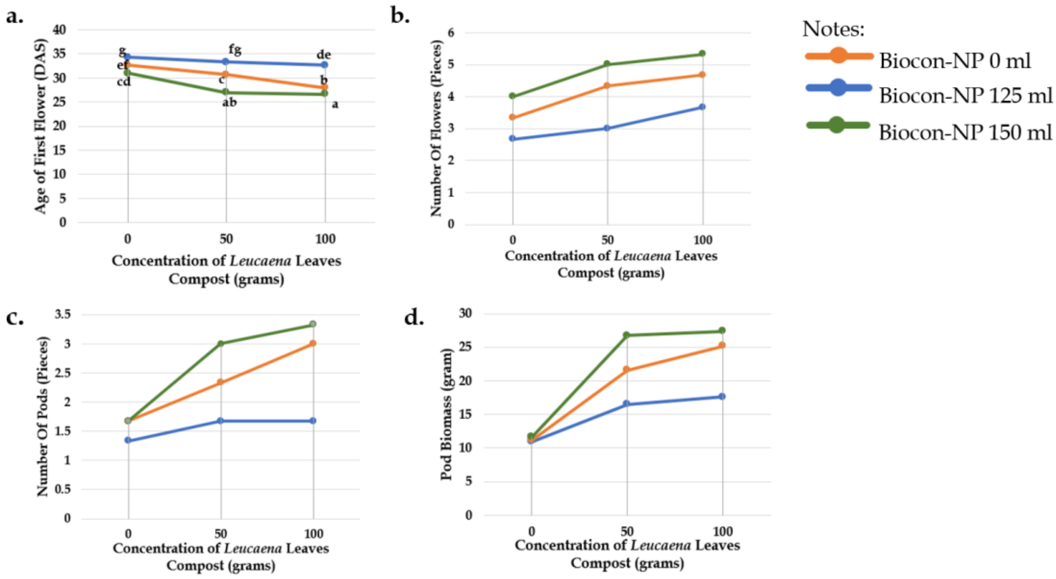


Figure 2. Effect of the combination of *Leucaena* leaves compost and Biocon-NP on a) age at first flower appearance, b) number of flowers, c) number of pods, and d) pod biomass (Different letters on the graph indicate significant effect based on Duncan's test at 0.05 level).

Leucaena leaves compost has a high content of macronutrients, including nitrogen, phosphorus, and potassium as it surpasses the SNI 19-7030-2004 minimum limits, which are 2.10%, 1.59%, and 1.57%, respectively. This indicates that composted *Leucaena* leaves contribute to meeting the N, P, and K nutrient requirements of nutrient-deficient Lapindo mud media. The longer the composting period, the more nitrogen is produced during the decomposition process. According to Trivana *et al.* (2017), high nitrogen levels affected the phosphorus content, which in turn increased the activation of microorganisms for the formation of potassium during composting. Ningsih *et al*. (2013) claim that the mineralisation process, which breaks down the available protein in *Leucaena* leaves into amino acids and lactic acid, causes an increase in N nutrients during the composting process.

The results have shown that using *Leucaena* leaves compost and Biocon-NP as a source of nutrients can affect the growth of long bean plants (Figures 1 and 2) on Lapindo mud media. Vegetative parameters (plant height, number of leaves, and active root nodule biomass) were significantly influenced by the interaction of *Leucaena* leaves compost and Biocon-NP, as shown in Figure 1. However, no significant effect was observed on wet biomass, root length, and root nodule biomass. The results showed that the combination of *Leucaena* leaves compost and Biocon-NP significantly affected the generative parameters of long bean plants (Figure 2), including the age of first flower appearance, the number of flowers, the number of pods, and pod biomass. At a concentration of 100 grams of *Leucaena* leaves compost with 150 ml of Biocon-NP, the flowering age was consistently accelerated productivity of long bean plants increased.

Pseudomonas sp. dissolves the P element present in *Leucaena* leaves compost, making it available for ATP formation in plants. ATP is a basic requirement for various cellular activities, such as cell elongation and enlargement, that occur in stems. This sufficient ATP availability then drives increased plant height (Marian and Tuhuteru, 2019). Jnawali *et al.* (2015) revealed that in addition to its role for N fixation, *Azotobacter* also produces compounds important for growth, such as GA and IAA. Meanwhile, *Azospirillum* sp. also produces cytokinin, IAA, auxin and gibberellin (Noviani and Rahayu, 2022). The presence of auxin hormones can cause cells in the stem to secrete hydrogen ions around the cell wall, reducing the pH and resulting in a loose cell wall, which facilitates rapid plant growth (Pamungkas and Puspitasari, 2018).

The significant increase in leaves on the plant is proportional to the plant's height, the taller the plant, the more leaves it will have. The number of leaves increases with plant height because the stem serves as a support for growing leaves (Anjani and Santoso, 2022). However, the number of leaves did not increase with 150 ml of Biocon-NP, while the plant height continued to increase at a concentration of 150 ml. It is because meristem cells have a greater division capacity compared to the differentiation process, so applying 150 ml of Biocon-NP can inhibit leaf formation. According to Tri and Nopiyanto (2020), excessive auxin can suppress leaf differentiation. If too much auxin is applied, cytokinin cannot function properly, resulting in less optimal leaf growth (Pamungkas and Puspitasari, 2018).

Plant growth rate can be measured in various ways, one of which is by measuring growth in wet or total wet weight. Based on research results, the highest treatment was obtained from the treatment of 100 g of *Leucaena* leaves compost and 150 ml of Biocon-N attributed to in plant wet varying the influence of responses to different nutrient doses on plant growth (Hidayanti and Kartika, 2019). The increase in biomass is due to the plants' ability to absorb more nutrients and water. Sufficient nutrient availability during photosynthesis allows the process to run smoothly, enabling assimilates to be translocated throughout the plant, increasing plant fresh biomass (Rahmah *et al*., 2014).

The symbiotic relationship between soil bacteria (*rhizobia*) and roots in legume plants produces root nodules that fix atmospheric nitrogen thru nitrogenase enzyme activity (Mahmud *et al*., 2020). According to Febriati and Rahayu (2019), the relationship between root nodules and nitrogen nutrients in soybean plants is directly proportional, the more the number of active root nodules, causes the amount of nitrogen nutrients in soybean plants increases. The mechanism of *Azospirillum* sp. And *Azotobacter* sp. in tethering nitrogen maintains a low concentration of oxygen in the cell by increasing the respiration rate. If the oxygen concentration is high, *Azotobacter* sp. does not activate the nitrogenase enzyme (Soumare *et al*., 2020). An alginate capsule forms on the cell surface, functioning in a novel mechanism to protect nitrogenase against oxygen (Sapalina *et al.,* 2020).

The presence of phytohormones such as cytokinins and auxins produced by *Azotobacter* sp., *Azospirillum* sp. and Pseudomonas can support root growth. According to Noviani and Rahayu (2022), Pseudomonas fluorescens is essential in forming the root zone because it produces growth-promoting phytohormones, such as IAA. Root growth assisted by phytohormones, can increase the activity of Rhizobium bacteria in forming root nodules. *Rhizobium* bacteria possess chemoorganic properties, enabling them to utilize carbohydrates and organic acid salts as carbon sources (Sari and Prayudyaningsih, 2015). The presence of active root nodules indicates that there is activity in the tethering of free N_2 by *rhizobium* (Fitria and Rahayu, 2025). Long bean plants are capable of symbiosis with Rhizobium bacteria, which can form root nodules.

Normal vegetative growth indirectly affected plant metabolism during the generative phase (Ihtiramiddin *et al.,* 2024). The emergence of flower buds on plants marks the change from the growth stage to the fruiting stage (Annisa and Gustia, 2018). According to the results, the plants that received 100 g of composted *Leucaena* leaves and 150 ml of Biocon-NP showed the earliest flower appearance at 26.67 days after planting, indicating that the maximum vegetative phase had ended and the generative phase had begun. The first flower on the Kanton Tavi variety typically blooms between 34 and 36 days after planting. This is because the availability of adequate nutrients influences the process of flower formation; P nutrients are one of the tethering factors used in the flowering process. According to Tovika *et al.* (2017), the element P is able to increase the synthesis of amino acids, such as methionine, which is a precursor of ethylene. This, in turn, causes physiological and morphological responses in plants, encouraging flowering and fruit formation. Additionally, the presence of bacteria that produce the hormone gibberellin, which accelerates the formation of flower organs, is also a contributing factor to the effectiveness of Biocon-NP biological fertilizer.

According to Gulo *et al*. (2020), plants require a balanced amount of nutrients to grow optimally and achieve maximum production. Chlorophyll formation requires the role of Nitrogen, which enhances photosynthesis and, thereby affects pod development. This aligns with Kurniawan *et al.* (2017), stated that if the number of pods on beans increases, the rate of photosynthetic activity is also high. According to research by Amir *et al.* (2017), increased root nodule formation in long bean plants can significantly enhance crop yield components, including the number of pods and seeds per pod. Active root nodule formation during the generative phase can meet the nitrogen requirements of legume plants. In the research by Vidiatama and Elfis (2024), it is mentioned that leaves and seeds affect fruit shape and dense seeds. An uneven number of pods produced by the plant reduces the appearance of fully filled pods, while nutrient availability can result in dense and well-shaped fruits and seeds, increasing seed weight in the plant.

CONCLUSION

The conclusion from the results obtained is that the application of *Leucaena* leaves compost and Biocon-NP has a significant effect on the parameters of plant height, number of leaves, root length, wet biomass, root nodule biomass, active root nodule biomass, flowering age, number of flowers, number of pods, and pod biomass. The interaction between *Leucaena* leaves compost and Biocon-NP significantly affected the parameters of plant height, number of leaves, active root nodule biomass, and flowerage. The combination of 150 ml of Biocon-NP and 100 grams of *Leucaena* leaves compost produced the best results. However, the best results were obtained with a concentration of 100 grams of *Leucaena* leaves compost and 125 ml of Biocon-NP in the number of leaves parameter. The best concentration was produced at 50 grams of *Leucaena* leaves compost and 150 ml of Biocon-NP in the root length parameter.

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CONFLICT OF INTEREST

There is no conflicts of interest.

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