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The Application of Goat Manure and Rhizobium on Contaminated Soil to Improve Growth and Yield of Mung Bean (*Vigna radiata*, L)

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ABSTRACT

Stone slurry, a byproduct of natural stone industry activities, has the potential to pollute agricultural land surrounding the industry, affecting both the physical and chemical properties of the topsoil. The aim of this research was to analyze the effect of goat manure and Rhizobium application on stone slurry-contaminated soil in order to improve the growth and yield of mung bean (Vigna radiata L.). A randomized block design (RBD) was arranged, including two factors: the doses of goat manure with three levels, namely 0 ton ha-1, 10 ton ha-1, 15 ton ha-1, and the doses of Rhizobium with three levels, 0 g kg-1 of seed, 7.5 g kg-1 of seed, and 15 g kg-1 of seed. The results showed that goat manure application had an independent effect on plant height and number of leaves at 28 days after planting (DAP), as well as on the number of pods per plot. Goat manure increased plant height and pod number by approximately 12-14% compared with the control treatment. However, its effect decreased during subsequent observation periods. Meanwhile, Rhizobium application did not significantly affect on all observed variables. Soil pH, nutrient availability, and soil physical properties as limiting factors affecting microbial activity, including both organic matter-decomposing microorganisms and Rhizobium as a nitrogen-fixing bacterium.

Keywords: contaminated soil, manure, mug beans, rhizobium, slurry.

1. INTRODUCTION

The natural stone industry is one of the rapidly growing industries in Cirebon Regency. This industry contributes to the regional economy by increasing employment opportunities and improving community income. However, stone mining and processing activities, including cutting and polishing, generate substantial waste. Stone slurry a byproduct of natural stone industry which consists of very fine particles which has to pollute surrounding agricultural land (Mosaferi et al., 2014; Singhal et al., 2020). The accumulation of stone slurry in the topsoil may alter soil properties. Soil contaminated by natural stone industry waste has been reported have low levels of essential nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K) (Nurfadilah et al., 2024). Furthermore, Adebiyi et al., (2021) reported that topsoil properties, including soil moisture,

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pH, and the availability of nutrients such as N, P, K, calcium (Ca), magnesium (Mg), and cation exchange capacity (CEC), were adversely affected by contamination, such as cement dust.

Ameliorating waste-contaminated soil properties can be effectively achieved through the application of soil amendments combined with biofertilizers. Soil amendments are materials that enhance the physical, chemical, and biological properties of soil, thereby improving crop productivity (Garbowski et al., 2023). These materials improve soil fertility by supplying essential nutrients, enhance soil structure by increasing aggregate stability and reducing bulk density, and stimulate soil microbial activity (Shu et al., 2022; Siedt et al., 2021). One organic amendment with considerable potential is manure. As an organic fertilizer, manure has positive influences on soil fertility (Hendarto et al., 2024) and increases soil pH, which subsequently enhances nutrient availability (Cerozi & Fitzsimmons, 2016). Furthermore, manure contains beneficial microorganisms that play an important role in the mineralization of essential nutrients (Pahalvi et al., 2021). To maximize the effectiveness of manure, co-application of biofertilizers such as *Rhizobium* can be a strategy for rehabilitating soil contaminated by natural stone industry waste. *Rhizobium* is a nitrogen-fixing bacterium that forms a symbiotic association with leguminous plants, enabling them to obtain nitrogen naturally through the formation of root nodules (Lucky et al., 2026).

Mung bean (*Vigna radiata* L.) is one of the legume crops widely cultivated in Indonesia. It serves as an essential source of protein and is considered a strategic food commodity due to its high protein content and nutritional value (Ridha Ayumnuazmi et al., 2025). However, mung bean productivity remains relatively low due to declining soil fertility, land-use change, and inadequate cultivation practices (Hastuti et al., 2018).

Previous studies have demonstrated that the application of manure (Baghlani et al., 2024; Diatta et al., 2023) and the inoculation of *Rhizobium* (Favero et al., 2022) in mung bean cultivation can enhance vegetative growth and yield potential. However, information regarding the use of manure and *Rhizobium* in soils contaminated by waste from the natural stone industry remains limited, particularly for mung bean cultivation. Therefore, this research aimed to analyze the effects of goat manure and Rhizobium application on stone slurry-contaminated soil to improve the growth and yield of mung bean (*Vigna radiata* L.).

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2. RESEARCH METHOD

This research was conducted from October to December 2025 in Bobos Village, Dukupuntang Subdistrict, Cirebon Regency, Indonesia. The experimental site was located on contaminated land due to the accumulation of stone slurry on the soil surface.

The experiment was arranged in a randomized block design (RBD) with two factors. The first factor was goat manure applied at three levels: 0, 10, and 15 t ha^{-1}. The second factor was *Rhizobium* inoculation at three levels: 0, 7.5, and 15 g kg^{-1} seed. The nine treatment combinations were replicated three times, resulting in 27 experimental units.

Each experimental plot measured 1.5 m × 1.5 m. Mung bean seeds were planted at a spacing of 25 cm × 25 cm, resulting in 36 plants per plot. Goat manure was incorporated into the soil seven days before planting during the second soil preparation. *Rhizobium* inoculation was carried out immediately before planting using a commercial inoculant (Rhizoka®) by coating seeds that had been soaked in water for 15 minutes. No inorganic fertilizer was applied during the experiment.

Initial soil properties, including soil pH, total N, available P, and exchangeable K, were determined from composite soil samples collected from five sampling points within the experimental area. Soil analyses were conducted at the Agronomy and Horticulture Laboratory, IPB University. Observed variables included plant height and number of leaves at 21, 28, and 35 days after planting (DAP), root volume, and the number of effective root nodules at 35 DAP. Yield observations included the number of pods per plot and pod weight per plot measured at harvest after the pods had been air-dried for seven days.

The data were analyzed using analysis of variance (ANOVA) at the 5% significance level. When significant treatment effects were detected, means were separated using Duncan's Multiple Range Test (DMRT) at the 5% significance level.

3. RESULT AND DISCUSSION

Soil Analysis

Initial soil analysis shows that the field research has soil pH as 7.66 (moderately alkaline), a total of Nitrogen as 0.15 (low), P_2O_5 as 11.5 (low), and exchangeable K as 0.32 (low). Based on this data, show that low soil nutrients and alkaline pH are limiting factors in mug bean cultivation.

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Plant Height

The effect of the treatment on average plant height is presented in Table 1. Table 1 shows the independent effect of goat manure application on average plant height at 28 days after planting (DAP), however, this effect was no longer observed at 35 DAP. Meanwhile, the application of rhizobium did not significantly affect the average plant height at any observation period.

At 28 DAP, goat manure application at 10 t ha^{-1} and 15 t ha^{-1} increased average plant height by 12-14% compared to no manure treatment. This finding is consistent with the results reported by Afontur et al, (2025), the application of goat manure significantly increased mung bean growth by improving nutrient availability, such N, P, and K. Goat manure, as an organic matter, provides both macro- and micronutrients required for plant growth. Furthermore, the addition of organic matter improves soil physical properties, such as reducing bulk density and enhancing soil structure, thereby creating favorable conditions for root development.

In this research, find that the effect of organic matter diminished at 35 DAP. The irrigation water source was contaminated by natural stone industry activities, containing high concentrations of carbonate (Ca) and suspended sediments. These sediments accumulated on the soil surface as fine rock particles, increasing soil pH. These conditions may have reduced microbial activity involved in nutrient mineralization from manure, including the activity of *Rhizobium* bacteria. Nitrogen is an essential nutrient for vegetative growth, particularly stem elongation, which contributes to the increase in plant height.

Table 1. Effect of Treatment on Plant Height (cm)

Treatment	Average of Plant Height (cm)		
	21 DAP	28 DAP	35 DAP
Goat Manure (A)			
A0 (0 t ha^{-1})	19.33 a	24.63 a	41.00 a
A1 (10 t ha^{-1})	20.63 a	27.54 b	42.17 a
A2 (15 t ha^{-1})	21.59 a	28.07 b	42.24 a
Rhizobium (P)			
P0 (0 g kg^{-1} of seed)	19.33 a	26.56 a	41.83 a
P1 (7.5 g kg^{-1} of seed)	20.63 a	27.22 a	41.69 a
P2 (15 g kg^{-1} of seed)	21.59 a	26.46 a	41.89 a

Note: Numbers followed by the similar letter not significantly different at 5% Duncan test level

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Number of Leaves

The analysis of variance presented in Table 2 shows that the application of goat manure significantly affected the average number of leaves at 28 DAP, yet no significant effect was observed at 21 and 35 DAP. Meanwhile, rhizobium treatment had no significant effect on the average number of leaves at all observation periods. Similar results were reported by Diatta et al. (2023), who observed that manure application increased leaf development by improving soil fertility and nutrient availability.

The research area, which was contaminated by natural stone industry activities, had low nutrient contents of N, P, and K. Meanwhile, goat manure, as a source of both macro- and micronutrients, releases nutrients gradually to support plant growth. According to Sharma et al. (2022) goat manure contains 1.67% N, 0.77% P_2O_5, and 0.85% K_2O. The availability of these nutrients supports vegetative growth, including the number of leaves. The increasing amount of leaves implies increased photosynthetic capacity, which support the vegetative growth phase

Table 2. Effect of Treatment on The Number of Leaves

Treatment	Number of Leaves		
	21 DAP	28 DAP	21 DAP
Goat Manure (A)			
A0 (0 t ha^{-1})	11.00 a	14.44 a	21.67 a
A1 (10 t ha^{-1})	12.11 a	16.04 b	22.37 a
A2 (15 t ha^{-1})	11.89 a	15.89 b	22.70 a
Rhizobium (P)			
P0 (0 g kg^{-1} of seed)	11.56 a	15.44 a	22.44 a
P1 (7.5 g kg^{-1} of seed)	12.11 a	15.41 a	21.96 a
P2 (15 g kg^{-1} of seed)	11.33 a	15.52 a	22.33 a

Note: Numbers followed by the similar letter not significantly different at 5% Duncan test level

In line with plant height, *Rhizobium* application had no significant effect on the number of leaves at any observation period. This is attributed to soil properties as a limiting factor for microbial activity, both the mineralization process and the fixation of biological nitrogen. The deposition of rock powder on the soil surface made the soil more compact and hard upon drying, while also increasing soil pH. These conditions may have restricted *Rhizobium* activity and reduced the effectiveness of biological nitrogen fixation. Soil properties, including bulk density and nutrient content, influence the composition and function of soil microbial communities in the rhizosphere, including phosphate-solubilizing and nitrogen-fixing bacteria (Wu et al., 2024).

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Root Characteristic

Roots are plant organs that play an important role in water and nutrient uptake, while also contributing to soil structure modification in the rhizosphere. The effects of the treatments on root characteristics are presented in Table 3.

Table 3. Effect of Treatment on Root Characteristic

Treatment	Root Volume (ml)	Effective Root Nodule
Goat Manure (A)		
A0 (0 t ha^{-1})	2.00 a	20.33 a
A1 (10 t ha^{-1})	1.50 a	18.33 a
A2 (15 t ha^{-1})	1.50 a	16.78 a
Rhizobium (P)		
P0 (0 g kg^{-1} of seed)	1.72 a	19.56 a
P1 (7.5 g kg^{-1} of seed)	1.83 a	17.89 a
P2 (15 g kg^{-1} of seed)	1.44 a	18.00 a

Note: Numbers followed by the similar letter not significantly different at 5% Duncan test level

Table 3 shows that the application of manure and *Rhizobium* had no significant effect on root volume or the number of effective root nodules. The combination of physical and chemical soil properties is suspected to be a limiting factor affecting soil microbial activity. Rhizobium inoculation is a mutualistic symbiosis between rhizobia and legume roots, through root infection and subsequent nodule formation (Ihtiramiddi et al., 2024). However, nitrogen fixation activity is strongly influenced by soil conditions and nutrient availability (Indah Cahyani Zega & Natalia Kristiani Lase, 2025), as well as soil type and soil properties (Abbaszadeh-dahaji et al., 2012).

The contaminated soil has a moderately alkaline pH. Alkaline soil conditions may inhibit microbial soil activity, both organic matter decomposers and nitrogen-fixing rhizobia. Declining microbial activity reduces nutrient mineralization from manure and biological nitrogen fixation. Furthermore, alkaline soils generally contain high concentrations of calcium (Ca), which can bind phosphorus (P) to poorly soluble calcium phosphate compounds, thereby reducing P availability (Elbasiouny et al., 2020). Phosphorus deficiency inhibits root nodulation and reduces legume productivity (Fan et al., 2024). As an essential macronutrient, phosphorus plays a critical role in ATP synthesis, which is required for atmospheric N_2 fixation. Therefore, phosphorus deficiency may reduce nitrogen fixation efficiency and restrict nodule development in leguminous crops (Isidra-Arellano & Valdés-López, 2024).

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Number of Pods and Pod Weight

The analysis of variance showed that manure application had an independent effect on the average number of pods per plot (Table 4). Goat manure increased the number of pods per plot by 12-14% compared with no manure treatment. However, neither manure nor rhizobium application significantly affected the average pod weight per plot.

Table 4. The Effect of Treatment on Average Number of Pods and Pod Weight

Treatment	Number of Pod	Weight of Plot (g)
Goat Manure (A)		
A0 (0 t ha^{-1})	244.44 a	244.27 a
A1 (10 t ha^{-1})	274.67 b	271.56 a
A2 (15 t ha^{-1})	279.56 b	279.32 a
Rhizobium (P)		
P0 (0 g kg^{-1} of seed)	261.00 a	260.81 a
P1 (7.5 g kg^{-1} of seed)	267.33 a	267.19 a
P2 (15 g kg^{-1} of seed)	270.33 a	267.14 a

Note: Numbers followed by the similar letter not significantly different at 5% Duncan test level

Legumes require adequate nutrient availability during the reproductive phase and pod ripening stages. Nutrient availability results in sufficient photosynthesis for plant biomass production, plant organ growth, pod filling, and ripening. Manure is an organic material that provides the macro- and micronutrients required by all plants, while *Rhizobium* help the biological nitrogen fixation through the root nodules formation. Nitrogen is an essential nutrient for the synthesis of protein and leaf chlorophyll. Chlorophyll plays a critical role during photosynthesis (Zhang et al., 2025), generating the photosynthates required for generative growth, including pod and seed formation (Du et al., 2024). As a macronutrient, the role of phosphorus is to provide energy in plant metabolism. Phosphorus also influences *Rhizobium* activity in nitrogen fixation. Meanwhile, potassium plays an active role in the translocation of photosynthates to other plant organs, thereby increasing the weight of dry matter in plant tissues, including seed weight (Tarigasa et al., 2022).

The results of the present study indicate that the contaminated soil environment limited the effectiveness of both manure and rhizobium. Nutrients contained in manure may not have been fully mineralized due to reduced activity of organic matter-decomposing microorganisms. Furthermore, *Rhizobium* activity and biological nitrogen fixation are restricted under the prevailing soil conditions. Elevated soil pH, high bulk density, and low nutrient availability are considered

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limiting factors affecting soil microbial activity. As a result, neither manure nor *Rhizobium* application produced a significant effect on pod weight per plot under these conditions.

4. CONCLUSION

Stone slurry, a byproduct of the natural stone industry, can adversely affect topsoil properties and limit mung bean growth. The application of goat manure significantly increased plant height and leaf number at 28 DAP, as well as the number of pods per plot. Goat manure has potential as a soil amendment for improving crop growth in agricultural soils contaminated by natural stone industry waste. Meanwhile, the application of *Rhizobium* did not significantly affect all observed parameters. The activity of soil microbes depends on soil properties. Soil pH, nutrient availability, and bulk density are the limiting factors of soil contaminated by natural stone industry activity, and these conditions affect the activity of soil microorganisms, including organic matter decomposers and nitrogen-fixing bacteria.

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