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Growth, Yield, and Phosphorus Uptake of Four Soybean Varieties on Biocomposted Coastal Lands

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ABSTRACT

Soybeans (Glycine max (L.) Merrill) are a popular food commodity in Indonesia, but domestic production is still insufficient to meet the demand. To increase production, planting superior varieties on coastal land could be a viable solution. Despite the challenging biological, physical, and chemical conditions of coastal land, nutrients such as phosphorus (P) are crucial for enhancing production. Typically, the phosphorus content in the soil is lower than that of nitrogen (N) and potassium (K), and the ability of soybean plants to absorb phosphorus varies among varieties. This research aims to compare the growth, yield, and phosphorus uptake of four soybean varieties on biocomposted coastal land. The study was conducted using a Randomized Complete Block Design (RCBD) with a single factor consisting of four soybean varieties: Wilis, Anjasmoro, Malika, and Detam 1. The results indicate that the Anjasmoro, Wilis, Detam 1, and Malika varieties exhibit similar responses in phosphorus absorption. However, the Anjasmoro and Wilis varieties demonstrate better adaptability compared to Malika and Detam 1, as evidenced by their superior growth and yield. This suggests that Anjasmoro and Wilis have a higher capability to adapt to the challenging conditions of coastal land. Therefore, these two varieties are recommended for cultivation in coastal areas to boost soybean productivity, ensuring the sustainability and stability of the national food supply.

Keywords: coastal, P uptake, soybeans, varieties

INTRODUCTION

Soybeans (*Glycine max* (L.) Merrill) are a vital food commodity in Indonesia, serving as a source of vegetable protein, industrial raw materials, and animal feed. The demand for soybeans continues to rise with the growing population. Efforts to meet national soybean production include increasing productivity, enhancing planting intensity, and expanding planting areas. Improving cultivation techniques by using high-yield, stress-adaptive superior varieties remains a promising approach (Asaad *et al*., 2024; Fattah *et al*., 2024; Sritongtae *et al*., 2021). Despite the release of many superior varieties by the government, adoption by farmers is still limited (Yardha, 2023). One significant challenge is the lack of fertile land to support the growth of these superior soybean varieties.

One strategy to expand agricultural land is by utilizing coastal areas, which have not yet been optimally exploited. Indonesia's coastline stretches 106,000 km, with a potential land area of 1,060,000 hectares suitable for agricultural development. The coastline of Bengkulu alone extends approximately 525 km. Coastal land is characterized by low fertility, particularly in terms of phosphorus (P) content. Coastal soils often suffer from erosion and nutrient degradation, impacting their fertility and plant growth (Garnier *et al*., 2021; Xie *et al*., 2022).

Phosphorus (P) is crucial for increasing soybean yields as it is a vital macronutrient for plant growth and development (Chávez-Mejía *et al*., 2024). It plays a key role in various physiological processes, such as photosynthesis, respiration, and energy formation. In photosynthesis, phosphorus is necessary for the formation of adenosine triphosphate (ATP), the primary energy source for cellular activities. Additionally, phosphorus is essential for cell membrane formation and maintenance, cell division, and DNA and RNA synthesis. Adequate phosphorus availability is critical for developing healthy and robust roots, enhancing the plant's ability to absorb water and nutrients efficiently (Chipatela *et al*., 2024). However, phosphorus deficiency in coastal soils poses a significant challenge due to frequent erosion and nutrient degradation, hindering optimal plant growth (Meng *et al*., 2021). Therefore, proper nutrient management and sustainable agricultural techniques are vital for improving coastal soil fertility and maximizing agricultural productivity in these areas.

One approach to enhancing soybean yields and improving coastal soil conditions is using composted coffee fruit skin waste (biocompost). Bengkulu is a major agricultural center that produces a substantial amount of agricultural waste, including coffee skin waste. Biocompost from coffee skin plays a crucial role in increasing phosphorus (P) uptake and soybean yields through various mechanisms (Bertham *et al*., 2018). Coffee skin, rich in organic and nutritional content, can be processed into biocompost to enhance soil fertility and provide nutrients for plants (Bertham *et al*., 2020). Biocompost increases the organic matter content of the soil, improves soil structure, enhances water absorption, and improves aeration, enabling soybean roots to absorb more nutrients, including phosphorus (Kranz *et al*., 2020). The decomposition process of biocompost by soil microorganisms produces organic acids that dissolve phosphorus, increasing its availability to plants. Furthermore, biocompost contains micronutrients that support soil microbial activity, such as mycorrhizae and phosphate-solubilizing bacteria, which help plants absorb phosphorus more efficiently (Yusra *et al*., 2021). Thus, using coffee hull biocompost as a sustainable nutrient management strategy not only addresses agricultural waste issues but also enhances soybean productivity and supports environmentally friendly agricultural practices.

MATERIALS AND METHODS

This research was conducted in Beringin Raya Village, Muara Bangkahulu District, Bengkulu City. The experimental design employed was a single-factor Randomized Complete Block Design (RCBD) with treatments consisting of four soybean varieties: Anjasmoro (V_1), Willis (V_2), Malika (V_3), and Detam I (V_4). Each treatment was replicated five times, resulting in a total of 20 experimental units. Each plot consisted of 50 plants, totaling 1000 plants across all plots. The data obtained were analyzed using analysis of variance (ANOVA) at a 5% significance level. Variables that showed significant differences in the F-test were further analyzed using the Least Significant Difference (LSD) test at a 5% significance level.

The research began with land clearing, followed by soil preparation and plot construction, with each plot measuring 3 m x 1.5 m and spaced 50 cm apart, with a 0.5 m distance between plot blocks. Coffee husk compost was applied at a rate of 10 tons per hectare (equivalent to 4.5 kg per plot) and incubated for one week. Planting was done by making planting holes with a sharp-tipped wooden stick, each hole approximately 5 cm deep, with a spacing of 30 cm x 30 cm. Two soybean seeds were placed in each hole, along with approximately 5 grains of Carbofuran, and the holes were then covered. Agricultural lime containing $CaMg(CO_3)_2$ was applied at a rate of 200 kg per hectare (equivalent to 90 g per plot) the day before planting, spread evenly between planting rows. Fertilizers applied at planting included 100 kg per hectare of Urea (45 g per plot), 100 kg per hectare of KCl (45 g per plot), and 100 kg per hectare of SP36 (45 g per plot). Urea fertilizer was applied twice: half at planting and the other half three weeks after planting, distributed evenly between planting rows.

Maintenance activities included watering, replanting, weeding, and pest and disease control. Harvesting was conducted during both the vegetative and generative periods. During the vegetative period, harvesting occurred when approximately 10% of the plants had flowered. During the generative period, harvesting was done when most of the leaves (90-95%) had turned brown and fallen, the leaves were old or yellow, the fruit had changed color from green to brownish-yellow and cracked, or the pods appeared old, and the stems were yellow, slightly brown, or brown. Observed parameters included phosphorus levels and uptake, plant dry weight (g), plant height (cm), plant harvest age (days), number of seeds per plant, seed weight per plant (g), and weight of 100 seeds (g).

RESULTS AND DISCUSSION

The research results show that it exists real difference tested varieties to plant height, harvest age, quantity plant seeds^{-1}, plant seeds weight^{-1} and the weight of 100 seeds, but there were no significant differences in tissue P content, P uptake, flowering age and plant dry weight (Table 1).

Table 1. Summary of ANOVA on growth , yield and P uptake on four varieties soybean

Variable	F-value	F table 5%
Tissue P levels plant	3.00 ns	3.49
P uptake	0.40 ns	3.49
Plant height	6.95* *	3.49
Plant Dry Weight	0.82 ns	3.49
Harvest Age	9.67*	3.49
Number of plant seeds $^{-1}$	4.84*	3.49
Plant seed weight $^{-1}$	69.20*	3.49
Weight of 100 seeds	85.20*	3.49

Note : * = significant ($p<0.05$); ** = highly significant ($p<0.01$); ns = non-significant ($p\geq0.05$)

Research results show that the Malika, Wilis, Anjasmoro, and Detam I varieties have similar responses to tissue phosphorus (P) levels, P uptake, and dry plant weight (Table 2). All these varieties exhibit the same pattern in phosphorus absorption from the soil and its influence on vegetative growth, particularly in terms of dry plant weight. This indicates that the physiological mechanisms used by these varieties to absorb and utilize phosphorus are not significantly different. The similarity in phosphorus uptake demonstrates that each variety has equivalent potential in utilizing this essential nutrient to support vegetative growth (Kaul *et al*., 2021).

Table 2. Average plant dry weight, P- tissue and uptake of 4 varieties soybean

Variety	Tissue P levels plant (%)	P absorption (g)	Plant dry weight (g)
Malika	0.34	0.017	4.15
Wilis	0.37	0.018	5.09
Anjasmoro	0.32	0.020	6.49
Detam 1	0.29	0.017	5.86

The similarity in dry plant weight among these varieties indicates that each variety has comparable efficiency in converting absorbed phosphorus into biomass. Dry plant weight is an important indicator of plant health and productivity, reflecting how well a plant allocates available resources for growth and development. With similar efficiency in phosphorus utilization, these varieties can be considered equivalent in terms of fertilization and nutrient management to enhance soybean productivity. These findings provide valuable insights for farmers in selecting the appropriate variety for cultivation without concern for significant differences in the ability to absorb and utilize phosphorus.

Table 3. Growth and yield four soybean varieties on bio-composted coastal lands

Variety	Plant height (cm)	Age harvest (days)	Amount plant seeds $^{-1}$ (seeds)	Plant seed weight $^{-1}$ (g)	Weight of 100 seeds (g)
Malika	62.22 a	89.00 b	208.00 b	18.88 b	12.86 c
Willis	63.13 a	89.40 b	249.56 a	30.92 a	14.58 b
Anjasmoro	61.67 a	87.60 b	217.26 b	31.98 a	16.86 a
Detam I	41.25 b	94.60 a	204.15 b	13.90 c	12.10 d

Note: Numbers followed by different letters in the same column are significantly different in the 5% LSD test.

According to the variety descriptions, the plant heights are as follows: Wilis at 50 cm, Detam I at 58 cm, Anjasmoro at 64-68 cm, and Malika at 60-80 cm. When compared to these descriptions, it is evident that the Wilis variety exhibits greater plant height, while the Anjasmoro and Malika varieties conform to their described heights, and the Detam I variety has a lower plant height. This indicates that the Wilis, Malika, and Anjasmoro varieties are better adapted to coastal land environments than the Detam I variety. Additionally, the Anjasmoro variety has a shorter harvest period.

The results of this research show that phosphorus uptake in the Anjasmoro variety tends to be higher than in the other varieties, leading to a faster harvest time. This is consistent with previous studies that have shown differences in soybean harvest periods can be attributed to varietal responses to phosphorus (Khan *et al*., 2020; Neenu *et al*., 2020).

The Wilis variety produces more seeds compared to the Detam I, Malika, and Anjasmoro varieties. However, both the Wilis and Anjasmoro varieties have equally good seed weights per plant (Table 3). This indicates that the Anjasmoro and Wilis varieties can adapt better to the environment compared to the other varieties. The high seed weight per plant is also supported by the efficiency of phosphorus (P) uptake in soybean plants. Maximum P absorption occurs during the seed-filling stage; when the plant's P needs are met, seed filling will be optimal, resulting in increased seed weight per plant (de Souza *et al*., 2022; Shitikova *et al*., 2024).

The Anjasmoro variety produced the highest 100-seed weight, which was significantly different from the other soybean varieties (Table 3). This increase in 100-seed weight is attributed to the genetic factors of the soybean variety. Larger seed size results in greater 100-seed weight and enhances the plant's ability to absorb nutrients from the environment (Sjamsijah *et al*., 2023). Additionally, the increase in 100-seed weight is also due to improved availability and uptake of phosphorus (P). Phosphorus is a key element in the seed formation process of soybeans, so enhanced availability and uptake of P in plants lead to an improved seed formation process and increased seed unit weight (Qi *et al*., 2020).

CONCLUSION

The Anjasmoro, Wilis, Detam I, and Malika varieties exhibit similar responses in absorbing phosphorus (P). However, the Anjasmoro and Wilis varieties demonstrate a higher level of adaptability compared to Malika and Detam I, as evidenced by their superior growth and yield. This indicates that Anjasmoro and Wilis are better able to adapt to coastal land conditions, which typically have biological, physical, and chemical properties that do not support optimal plant growth. Therefore, these two varieties are recommended for cultivation in coastal areas to increase soybean productivity, ensuring the sustainability and stability of the national food supply.

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