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Growth and yield of bok choy (*Brassica rapa* L.) plants in post-rock excavation soils provided with phosphate-solubilizing bacteria and manure

Abstract. Elevated sand and gravel mining to meet market needs causes negative impacts on the environment, soil, and biodiversity. The government issued a regulation that requires revegetation as reclamation of mineral and coal mining. The conversion needs to overcome the physical and chemical characteristics of post-rock excavation soil that can be utilized by economic value plants such as bok choy. This experiment aimed to determine the growth and yield of bok choy on post-rock excavation soil by providing phosphate solubilizing bacteria (PSB) and various manure types. The study was conducted in Margasari Village, Buah Batu District, Bandung at an altitude of 671 m above sea level and at the Soil Biotechnology Laboratory, Faculty of Science and Technology, UIN Sunan Gunung Djati Bandung from April to June 2023. The experimental design used was a factorial Randomized Block Design (RBD) with two factors and repeated three times. The first factor was PSB isolate dose (without PSB; 5 mL polybag^{-1}; 10 mL polybag^{-1}; 15 mL polybag^{-1}, and 20 mL polybag^{-1}). The second factor was manure variety (cow, goat, and laying hen manure, each of 15 t ha^{-1}). The parameters observed comprised the soil and plant parameters. The results showed that there was no interaction between the dose of PSB isolate and various types of manure on the growth and yield of bok choy plants. The PSB isolate and manure had not been able yet to increase the growth and yield of Bok Choy (*Brassica rapa* L.) plants on post-rock excavation soil, mainly due to the soil nature.

Keywords: Bok choy · Growth · Manure · Phosphate Solubilizing Bacteria (PSB) · Post-rock excavation soil

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Introduction

High mining of sand and gravel to meet market needs causes various negative impacts such as air pollution, changing the pH of water to acid, as well as loss of biodiversity(Lei et al., 2016), decreasing soil quality in the form of a reduction in the ability to absorb and retain water, lack of nutrients, and susceptible to erosion(Ginting et al., 2018). On the other hand, the total P-nutrient content in the soil after rock excavation is found in high amounts of 156.44 mg.100g^{-1} in Cibeureum village, Sumedang district. Ramadhan et al., (2015), 135.69 mg 100g^{-1} in Cimareme, West Bandung district (Hidayat et al., 2020), 160.96 mg 100 g^{-1} originating from Mount Galunggung, Tasikmalaya district (Hidayat et al., 2023). This condition shows the potential for using soil from post-rock excavation for plant cultivation. However, technological input is needed to convert non-available P into available P that can be utilized by plants.

The utilization of post-rock excavation land is in line with regulations issued by the government as stated in Law No. 03 of 2020 concerning mineral and coal mining. This regulation requires revegetation as a criterion for successful reclamation. This indicates the potential for using post-mining soil as agricultural land. It is hoped that the conversion of land functions can be used to increase crop production, especially those with high economic value such as bok choy.

Bok choy (*Brassica rapa* L.) is a leaf vegetable that is widely consumed by the public. Nitrogen (N) potassium (K), and phosphorus (P) elements are needed in high amounts to support the growth of leaf vegetables(Bahri et al., 2020). The P element in leaf vegetables has an important role in photosynthesis, respiration, and other metabolic reactions (Bahri et al., 2020). Cultivating bok choy in post-rock excavation soil, which has minimal nutrients, means that efforts are needed to increase essential nutrients such as N and K, as well as releasing total P into available P, so that it can be utilized optimally by bok choy plants.

The efforts to overcome the problem of decreasing soil quality and low available P can be achieved by applying PSB. Soil pos-rock excavation has been identified to contain indigenous bacteria such as *Bacillus megaterium* and *Pseudomonas aeruginosa* (Sariwahyuni, 2012). PSB is a bacteria that can convert bound phosphate into soluble and is available through the production of organic acids such as 2-Ketogluconic and gluconic acid (Kishore et al., 2015). Furthermore, organic acids can chelate Fe, Al, and Ca ions bound to phosphorus and release them so that the P element becomes available and can be absorbed by the plants (Sharma et al., 2013; Campos et al., 2018) . Lovitna et al. (2021) showed that the application of PSB at a dose of 100% + 150% SP-36 on Alfisol soil could increase available P from 21.65 ppm (0 DAP) to 29.68 ppm (8 DAP). PSB performance can be optimized by adding organic material, especially in post-excavated rock soils that have very low C-organic content, such as C-organic in Cibeureum village, West Bandung district, 0.86% (Hidayat et al., 2020) and C-organic in Mount Galunggung Tasikmalaya district 0.19% (Hidayat et al., 2023).

Organic material can be plant or animal remains such as cow, goat, and chicken manure. These three animals are widely farmed in Indonesia so their manure is available in abundance and has the potential to be processed into fertilizer. According to Kadir et al. (2016) organic material can unite soil particles, increase the soil's capacity for water, and add nutrients N, P, K, Ca, Mg, S, and Fe. Apart from that, soil C-organic levels can also be increased by applying organic manure (Chairunnisya et al., 2017)

Organic materials can act as a source of food and energy for PSB microbes (Fitriatin et al., 2014). Meanwhile, PSB works to help decompose organic materials. The combined application of PSB and organic materials is expected to provide a synergistic effect on improving soil quality after rock excavation, so this research was conducted to determine the application of PSB and manure on the growth and yield of bok choy plants in post-rock excavation soil.

Materials and Methods

The research was conducted in Margasari Village, Buah Batu District, Bandung, West Java Indonesia at an altitude of 671 meters above sea level (6 º 57'11''S 107 º 38'56"E) and at the Soil Biotechnology Laboratory, Faculty of Science and Technology, University Islam Negeri Sunan Gunung Djati Bandung from April to June 2023.

The tools used in this research included a hoe, a 0.5 cm hole sieve, a ruler, digital scales, analytical scales, paper envelopes, plastic, polybags measuring 30 cm x 30 cm, watering can,

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stationery, thermohygrometer, seedling tray, plant labels, measuring cup, petri dish, micropipette, oven, autoclave, shaker, hot plate, Munsell Plant Tissue Color Book, LAF.

The materials used in this research include post-excavated soil from the mining area of Cimareme District, Bandung Regency. The organic materials have been applied 3 times during 3 growing seasons, green variety bok choy seeds, PSB was isolated from the exploration at the post-excavation site for Patrol rocks, Bandung Regency which is the collection of the Soil Biotechnology Laboratory, UIN Sunan Gunung Djati Bandung, cow manure, goat manure, laying hen manure, urea fertilizer, SP-36 fertilizer and KCl fertilizer, distilled water, mineral water, Pikovskaya broth media, Pikovskaya agar, and water.

The experimental design used was a factorial Randomized Block Design (RBD) with two factors, namely PSB isolate variety (m) with five treatment levels and manure variety (p) with 3 treatment levels, repeated 3 times. The first factor was the dose of PSB isolate, namely m_0: without PSB isolate, m_1: PSB isolate = 5 mL polybag^{-1}, m_2: PSB isolate = 10 mL polybag^{-1}, m_3: PSB isolate = 15 mL polybag^{-1}, m_4: PSB isolate = 20 mL polybag^{-1}. The second factor was the variety of manure, namely: p_1: cow manure 15 t ha^{-1} (30 g polybag $^{-1}$), p_2: goat manure 15 t ha^{-1} (30 g polybag^{-1}), p_3: laying hen manure 15 t ha^{-1} (30 g polybag^{-1}).

The observation parameters observed comprised on the soil and plant parameters. Initial soil analysis included soil texture, pH, C-Organic, C/N Ratio, N, P, K, and soil CEC (Cation exchange capacity). The manure's analysis included pH, C-Organic, N, P, K, and water content. Analysis of soil and manure for laying hens was carried out at the Laboratory of the Agricultural Instrument Standardization Agency (BSIP) for Vegetable Crops, Lembang, West Bandung Regency. Analysis of cow and goat manure content was at the Laboratory of the Department of Soil Science and Land Resources, Bogor Agricultural Institut by CV Mitra Tani Farm.

Plant height was measured at the age of 7 – 35 DAP once a week from the base of the stem to the highest part of the plant. Leaf area observation was carried out at 35 DAP (after harvest) and measured using the gravimetric method. Leaf color observation was done once at 35 DAP (at 7 AM just before the plants were harvested) using Munsell Plant Tissue Color Book. Observation of plant fresh weight was carried out by weighing plant samples from each treatment immediately after the plants were harvested, the whole parts of the plant including damaged parts were weighed using a digital scale.

The data obtained were analyzed using variance analysis (ANOVA). If there was a treatment effect, continue with the Duncan Multiple Range Test (DMRT) at the 5% level. The data processing used the DSAASTAT program).

PSB application was started by preparing isolates. PSB isolates were the collection of Biotechnology Laboratory UIN Bandung originating from soil post-excavation of Cimareme rocks, West Bandung district. The isolates were grown in shaken liquid Pikovskaya media for 3 x 24 hours using shaker at a speed of 150 rpm. Then, it was grown on solid Pikovskaya agar media in a petri dish for serial dilutions up to 10^9. Bacteria in petri dishes were incubated upside down for 3 x 24 hours at room temperature. All of these stages were carried out aseptically in Laminar Air Flow (LAF). The growing bacterial colonies were counted using the Total Plate Count (TPC) method with the Colony Counter tool. A total bacterial population of 30 x 10^6 CFU g^{-1} was obtained with varying bacterial sizes and clear zone (halo zone) sizes.

Bacteria that grew using the streak plate method with a total bacterial population of 30 x 10^6 CFU g^{-1} were taken entirely using ose needle and inoculated into Pikovskaya broth media in a glass bottle and shaken using a shaker for 3 x 24 hours. Next, the PSB isolate was diluted in mineral water according to the water content of the field capacity, which was 1 L, and applied according to the treatment, namely 5 mL, 10 mL, 15 mL, and 20 mL per polybag by pouring it evenly onto the ground in the polybag. The application of PSB was carried out 4 weeks after the application of drum fertilizer.

The post-excavated rock soil, which had been applied with organic material 3 times during three growing seasons, was sieved using a 0.5 cm soil sieve. Then, put it in a polybag measuring 30 cm x 30 cm, each polybag contains 4 kg of soil. Seeds were sown for 14 days in seedling trays or until the plants had three leaves. The seedling tray was filled with husk charcoal planting medium. Two seeds of bok choy were planted for each hole of the seedling tray. The manures used consisted of cow, goat, and laying hen manure, each of which was 15 t ha^{-1} (30 g polybag $^{-1}$). Organic manure fertilization was carried out 4 weeks before PSB application. Manure application was done by mixing the fertilizer with the soil in a polybag until evenly mixed.

Inorganic fertilizers used were Urea, SP-36, and KCl. Bok choy planting inorganic fertilization dosage refers to Haryanto (2007). SP-36 and KCl fertilizers were given 3 days before planting at half dose of 100 kg ha^{-1} (0.1 g $polybag^{-1}$) and 50 kg ha^{-1} (0.1 g $polybag^{-1}$) respectively, while urea was given 10 days after planting at a dose of 100 kg ha $^{-1}$ (0.2 g $polybag^{-1}$). The fertilizers were spread around the planting area.

Bok choy plant seedlings from the nursery were transferred to polybags measuring 30 cm x 30 cm with a planting hole depth of ± 5 cm, one seedling for each polybag. Planting distance between polybags was 20 x 20 cm. The planting was carried out at 06.00 AM to avoid wilting of the plants.

Plant maintenance included watering, re-planting, weeding, and pest and disease control. Watering was done at 07.00 AM and 05.00 PM, but the watering would be skipped for the rain. Replanting was carried out up to 7 DAP to replace bok choy plants that did not grow perfectly. Weeding was done manually by removing weeds that grew around the planting zone every 3 days from 7 – 35 DAP. Pest and disease control was carried out mechanically, namely by picking them up by hand and throwing them away from the research location.

The plants were harvested at the age of 35 DAP with the following harvest criteria: mature leaves with semi-round (oval) and wide, the leaf stalks were dark green, and the shape and size were relatively short. Harvesting was done by removing all parts of the plant from the ground.

Results and Discussion

Initial Soil Analysis. Based on the results of post-excavation soil analysis, the rock used had a sand fraction of 56%, 22% dust, and 22% clay (sandy clay texture class). This soil texture is relatively suitable for bok choy plants (Fatima et al., 2022). From the chemical properties of the soil, it was found that N was classified as very low (0.06%), organic C was very low (0.49%), available P was very high (73.0), and total P was classified as high (86.83 ppm) (Table 1).

Table 1. Soil analysis after rock excavation in Cimareme District.

Parameters	Value	Explanation
Sand, dust, clay (%)	56%, 22%, 22%	Sandy Clay Loam
pH	6.7	Neutral
C-organic (%)	0.49	Very low
N (%)	0.06	Very low
P-available (ppm)	73.0	Very high
P-total (mg 100g $^{-1}$)	86.83	Very high
K-available (ppm)	318.8	Very high
K-total (mg 100g $^{-1}$)	45.13	Very high
CEC	29.31	Tall

Description: Results of soil analysis at the laboratory of the Agricultural Instrument Standardization Agency (BSIP) for vegetable Crops, Lembang, West Bandung Regency

Table 2. Analysis of pH and nutrient contents of manures.

Parameters	Cow	Goat	Laying Hens	*Quality Standards
pH	8,11	6.3	8.8	4-9
C-organic (%)	40.52	43.21	19.51	Min.15
N (%)	1.33	1.03	2.24	Min.2
P_2O_5 (%)	0.45	0.54	4.27	Min.2
K_2O (%)	0.41	1.21	2.27	Min.2

Description: Analysis results based on manure content tests at the soils science and land resources laboratory, Bogor Agricultural Institute (IPB) (2022) and at the Agricultural Instrument Standardization Agency (BSIP) Laboratory for Vegetable Crops, Lembang, Bandung Regency (2023). *Quality standards based on RI Minister of Agriculture Decree No.261/KPTS/SR.310/M/4/2019.

Table 3. Effect of PSB and types of manure on plant height.

PSB	Average Plant Height (cm)				
	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP
m_0 (0 mL polybag^{-1})	3.27 a	8.32 a	14.72 a	16.61 a	17.61 a
m_1 (5 mL polybag^{-1})	3.23 a	7.10 a	14.32 a	16.56 a	18.02 a
m_2 (10 mL polybag^{-1})	2.38 a	7.37 a	14.48 a	17.09 a	18.49 a
m_3 (15 mL polybag^{-1})	3.93 a	8.34 a	15.71 a	17.16 a	18.01 a
m_4 (20 mL polybag^{-1})	3.00 a	6.66 a	13.53 a	15.90 a	17.80 a
Manure (15 t ha^{-1}/ 30 g polybag^{-1})					
p_1 (cow)	2.77 a	7.43 a	13.64 a	16.47 a	17.68 a
p_2 (goat)	3.53 a	8.30 a	15.22 a	17.11 a	18.29 a
p_3 (laying hen)	3.18 a	6.95 a	14.79 a	16.41 a	17.99 a

Note: The average numbers followed by the same letter show no significant difference according to Duncan's advanced test at the 5% level.

Plant Height. The application of PSB and various types of manure did not show an independent or interaction effect on plant height at 7, 14, 21, 28, and 35 DAP (Table 3). PSB independently had no significant effect on plant height. This was related to the low bacterial population (30 x 10^6 CFU g^{-1}). This population does not yet meet the quality standards for biological fertilizer according to the Republic of Indonesia Minister of Agriculture Decree No.261/KPTS/SR.310/M/4/2019, namely 1 x 10^8 CFU g^{-1}. Apart from the low bacterial population at the time of application, the very high available P content in the initial soil (Table 1) can reduce the bacterial population. Suparnorampius et al. (2020) stated that P-available in the soil has the opposite effect on the population of PSB. The rhizosphere of mustard plants with P-available levels of 15.03 ppm produced a bacterial population of 9 x 10^4 CFU g^{-1}, while the carrot rhizosphere with an available P level of 12.11 ppm produced a higher bacterial population, namely 10 x 10 ^{4} CFU g^{-1}. Chapelle (2001) also explains that the growth of microorganisms is influenced by the availability of ready-to-use phosphorus compounds in their habitat. Too much available P can inhibit the activity of PSB itself which has an impact on reducing the bacterial population. Furthermore, bacterial populations are related to the amount of organic material that can be decomposed, as well as the mineralization of organic material to become inorganic so that it can be utilized by plants (Octaprama et al., 2020). Thus, a decrease in the PSB microbial population can have an impact on not maximizing the organic material from manure that can be used by plants to support plant height.

The variety of manure independently did not have a significant effect on plant height. This was because the nitrogen (N) content in manure generally cannot meet the needs of plants. The N requirement for bok choy plants according to Uchida (2000) is N of 2.39% (239 ppm). This amount is still above that provided by the manure used, namely cow manure only provided N of 1.33% (133 ppm), goat manure 1.03% (103 ppm), and chicken manure 2.24% (224 ppm). This means that the plants were still lack the nutrient N by 0.15 – 1.2%. According to Wijaya et al. (2022) leafy vegetable plants, especially annual plants such as bok choy, require large amounts of N to increase the production of amino acids in the plant body. N functions in the division of cells in meristem tissue which causes stem elongation resulting in an increase in plant height. Lack of N elements in this case causes the formation of vegetative organs to be hampered, especially stems which determine plant height because the photosynthate results obtained are not optimal (Pramitasari et al., 2016).

Apart from the nutrient N, plant height is also influenced by the element P. The element P is needed by plants for the formation of new cells in growing tissue, as well as strengthening stem reproduction (Rahmawati et al., 2019). In this study, the availability P is suspected to come from the work of microbes contained in manure as stated by Chen et al. (2022) that manure will increase soil microbes, then these microbes promote the transformation of moderately labile P (M-P) to labile P (L-P). This is in line with Brucker et al. (2020) that microbes released exopolysaccharides and siderophores that both work as chelator and manure provided as C source

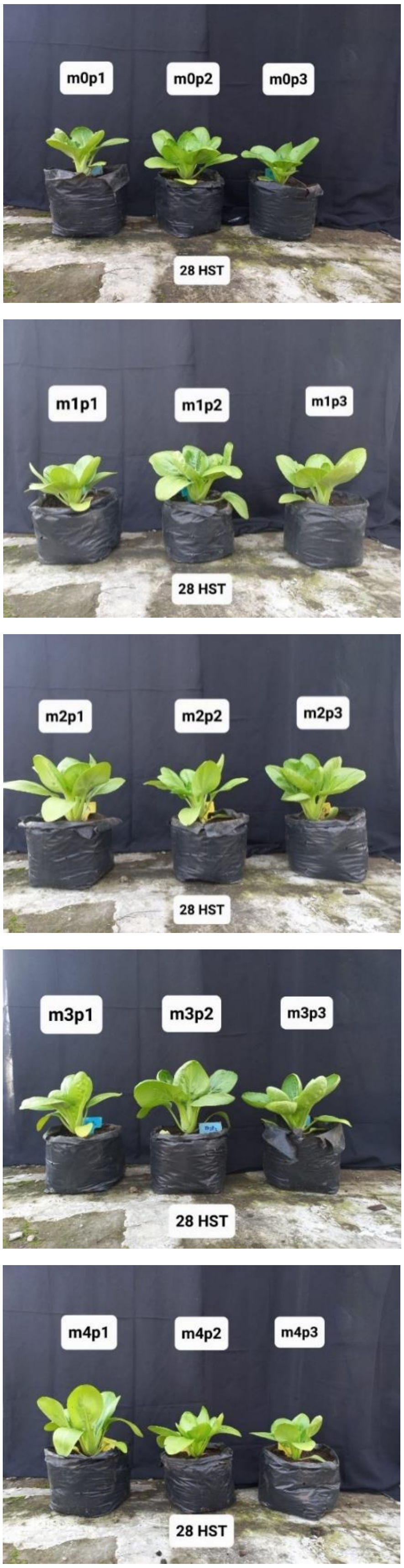

Figure 1. Comparison of bok choy plant growth in all treatments at 28 DAT

to make P solubilization rates increase. Excess P elements in plants can reduce plant height. This is in line with research (Firmansyah et al., 2015) that excess P causes the height growth of mangosteen plants to be hampered. The high level of P nutrients causes an antagonistic effect which causes a reduction in other nutrients, namely Zn and Fe (Sukmasari et al. , 2016). Zn plays a role in auxin synthesis with cell wall development and cell differentiation (Sivaiah, 2013). Meanwhile, Fe is responsible for activating enzymes and is a protein component that can stimulate plant height growth (Yolanda et al., 2020) . Therefore, the lack of these two elements due to high P is a supporting factor causing plants to grow stunted.

Leaf Area. Application of PSB and various types of manure fertilizer in interaction did not affect leaf area. Independently, the dose of PSB isolate also had no significant effect on leaf area, but the variety of manure had a significant effect on leaf area (Table 4). The application of various types of manure independently had a significant effect on increasing leaf area. Providing manure from laying hen produced the highest leaf area, namely 199.56 cm^2, this value was significantly higher to treatment with cow manure (134.34 cm^2) and goat manure (141.52 cm^2). The increase in leaf area is closely related to the availability of the nutrient N in plants as a form of plant vegetative organs. The N nutrient contained in laying hen manure, namely 2.24% (224 ppm), was not able to meet the N needs of plants, the same as the N element in cow manure 1.33% (133 ppm) and goats 1, 03% (103 ppm). Meanwhile, the N requirement for bok choy plants according to Uchida (2000) is 2.39% (239 ppm). However, if it is seen other factors, namely the C-organic value, laying hen manure had the lowest C-organic value, namely 19.51%. With this value divided by the N value (Table 1), a lower C/N ratio was obtained. This means that when applied, the laying hen manure had a better level of maturity than cow and goat manure, so the N nutrient contained in the laying hen manure was more readily absorbed by plant roots. According to Amnah & Friska, (2019) one of the components of plant tissue is carbon (C), during the composting process, carbon is used by bacteria as an energy source in constructing microbial cells by releasing CO_2 and other materials that evaporate. Therefore, there is a decrease in organic C levels in manure due to the breakdown that occurs during composting. The lower the C-organic content of manure indicates the better

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decomposition process carried out by microorganisms during the composting process. High C-organic in cow (40.52%) and goat (43.21%) manure implies that the composting process of organic material continues when the fertilizer is applied to the soil, and in these conditions, it is possible to reduce nutrient levels that plants need. The greater availability of organic compounds needed by plants from laying hen manure, especially N, causes the leaves to form wider than the other two treatments of cow and goat manure.

Table 4. Effect of PSB and Types of Manure on Leaf Area

PSB	Average (cm^2)
m_0 (0 mL polybag^{-1})	147.27 a
m_1 (5 mL polybag^{-1})	175.92 a
m_2 (10 mL polybag^{-1})	147.04 a
m_3 (15 mL polybag^{-1})	140.30 a
m_4 (20 mL polybag^{-1})	181.85 a
Manure	
p_1 (cow 15 t ha^{-1})	134.34 a
p_2 (goat 15 t ha^{-1})	141.52 a
p_3 (laying hen 15 t ha^{-1})	199.56 b

Note: The average numbers followed by the same letter show no significant difference according to Duncan's advanced test at the 5% level.

The N element released by organic materials plays a role in compiling nucleic acids and proteins involved in the formation of chlorophyll (Widiyawati et al., 2014). If the plant's N needs can be met, more chlorophyll will be formed. According to Rachmadhani et al. (2018) if a large amount of chlorophyll is formed, more sunlight can be absorbed, the rate of plant photosynthesis increases, and ultimately the yield of photosynthesis also increases (Garfannsa et al., 2021) . In this research, the N content in various types of manure was still relatively low and could not meet the needs of plants. The phenomenon of no difference in leaf area between treatments due to N deficiency was also proven in the color parameters of the bok choy leaves produced. Bok choy leaves experienced pale leaves turning yellowish green which is an indication that the plant lacks the nutrient N.

Leaf Color. Determining leaf color refers to the standard colors contained in the Munsell Plant Tissue Color Book (MPTC). Color in this book consists of 3 variables, namely hue, value, and chroma. Hue is the dominant color of the spectrum according to wavelength. Value describes how light or dark a color is, while chroma describes how weak or strong a color is (Liana et al., 2023). The hue scale runs vertically from the lightest, with a value of 2.5 (at the top), to the darkest, with a value of 5 (at the bottom). The hue in all treatments in the study showed that the leaves were Green Yellow (GY) with the most intense level of yellowish green. The value scale is also read vertically, the further down it is, the brighter it is. The value for all treatments has a value of 7, which is the second highest value. This means that bok choy leaves are very bright. Meanwhile, the chroma scale runs horizontally, moving from weak (left) to strong (right), chroma in all treatments has values of 6 and 8, which means it is classified as strong (Table 5).

Table 5. Effect of PSB and Manure Variety on Leaf Color

PSB	Leaf Color
m_0 (0 mL polybag^{-1})	5GY 7/6
m_1 (5 mL polybag^{-1})	5GY 7/8
m_2 (10 mL polybag^{-1})	5GY 7/6
m_3 (15 mL polybag^{-1})	5GY 7/6
m_4 (20 mL polybag^{-1})	5GY 7/6
Manure	
p_1 (cow 15 t ha^{-1})	5GY 7/6
p_2 (goat 15 t ha^{-1})	5GY 7/6
p_3 (laying hens 15 t ha^{-1})	5GY 7/6

Note: GY = Green Yellow ; 5GY = Hue ; 7/6 = Value/Chroma

The color of the bok choy leaves in all treatments at the end of the observation produced a relatively uniform color, namely yellowish green. The color of the leaves from this observation was lighter than the color stated in the description of the bok choy plant, where the color should be dark green. Pale leaf color is synonymous with a lack of nitrogen. This is in line with the results of the initial soil N analysis which was very low at 0.06% (6 ppm) and manure which was still below the needs of plants, where the N contained in cow manure was 1.33% (133 ppm), goat manure 1.03% (103 ppm), and laying hen manure 2.24% (224 ppm). On the other hand, according to Uchida (2000) bok choy requires a minimum N of 2.39% (239 ppm) resulting in a shortage of N elements of 0.15 – 1.2%. The nitrogen element forms chlorophyll which plays a role in giving leaves the green color (Setyanti et al., 2013). Therefore, N deficiency results in a color that is paler than the original color.

Apart from the lack of N, the color of the leaves turning yellowish green was thought to be caused by the high accumulation of K. The K nutrient available in the initial soil was 318.8 ppm, which is classified as very high. Next, the source of K nutrients in plants was also obtained from cow manure at 0.41% (41 ppm), goat manure at 1.21% (121 ppm), and laying hen manure at 2.27% (227 ppm) as well as fertilizer KCl dose was 100% (6 ppm), so that the K element available to plants was in excess by 0.7 – 2.2%. Element K is antagonistic to the element magnesium (Mg). Ding et al. (2006) stated that an antagonistic effect between K and Mg will appear if the K element is given in excess to plants, resulting in low Mg availability. It is important to know that not only nitrogen but Mg also plays an important role in the availability of chlorophyll in leaves.

According to Garfannsa et al. (2021) the green substance in leaves (chlorophyll) is also formed by the element Mg. Mg is the only metal ion contained in chlorophyll. Therefore, low Mg due to excess K can reduce chlorophyll content and also have an impact on the photosynthesis process of plants. This has been proven in research which shows that the application of 225 kg ha^{-1} KCl fertilizer produces a lower average chlorophyll content in sweet potato leaves, namely 920 µm fresh $weight^{-1}$ compared to the 78 kg ha^{-1} treatment which can produce higher chlorophyll, namely reaching 1060 µm fresh $weight^{-1}$. It can be concluded that chlorophyll is formed by the presence of the elements N and Mg. In this study, these two elements were insufficient in number.

Plant Fresh Weight. The application of PSB and various organic materials did not show any interaction or independent effects on plant fresh weight. Based on the research results, the fresh weight of bok choy plants obtained ranged from 75.0 – 91.4 g plant $^{-1}$ (Table 9). The fresh weight values were still below the plant description. The description states that the crop yield that can be obtained is 30 tons ha^{-1} or the equivalent of 120 g of $plants^{-1}$.

According to Mariay et al. (2023) the water content in plants will increase in line with the increase in nitrogen (N) content, thereby increasing the fresh weight of a plant. This happens because nitrogen plays a role in the formation of vegetative organs, namely leaves, stems, and roots. The higher and heavier the vegetative organs, the heavier the fresh weight of the plant. This is supported by Manuhuttu et al. (2018) who stated that fresh weight is the increase in the number of organs such as leaves, stems, and roots, which is influenced by the water content and nutrient content in plant tissue cells. In general, the N needs of bok choy plants were not met, so the formation of vegetative organs was hampered, the plants were stunted and the organs produced were small, as a result, the fresh weight of the plants was low.

Table 2. Effect of PSB and manure variety on plant fresh weight.

PSB	Average (g)
m_0 (0 mL $polybag^{-1}$)	91.4 a
m_1 (5 mL $polybag^{-1}$)	81.7 a
m_2 (10 mL $polybag^{-1}$)	84.7 a
m_3 (15 mL $polybag^{-1}$)	82.4 a
m_4 (20 mL $polybag^{-1}$)	75.9 a
Manure	
p_1 (cow 15 t ha^{-1})	75.0 a
p_2 (goat 15 t ha^{-1})	90.9 a
p_3 (laying hen 15 t ha^{-1})	83.8 a

Note: The average numbers followed by the same letter show no significant difference according to Duncan's advanced test at the 5% level.

The fresh weight of plants in relation to water content is also influenced by the availability of the element potassium (K). Potassium plays a role in regulating plant turgor pressure and osmosis. According to Wijaya et al. (2022) the element K can be absorbed by plants in the form of K^+ ions and plays a role in encouraging water absorption. Water absorption begins with the absorption of water by guard cells, which then causes an increase in cell turgor pressure which encourages the opening of the stomata. Open stomata provide a pathway for CO_2 and water to enter the plant so that the rate of photosynthesis increases. Furthermore, photosynthesis is used by plants for growth. According to Kurniawan et al. (2017) Sufficient K availability makes water use more efficient and maintains turgor, thereby facilitating metabolic processes. In this study, there was an excess of K. According to Uchida (2000), the K requirement for bok choy plants was 2.86% (286 ppm). The available K nutrient in the post-rock excavation soil was 3.188% (318.8 ppm), exceeding the plant K requirement of 0.328% or 38.2 ppm, and the excess nutrient value increases to 0.47% - 1.92% if K is accumulated with fertilizer cages and inorganic fertilizer. Besides that, the soil used has a pH of 6.7 (neutral). According to Silahooy et al., (2022) , K^+ ions are widely available in soil with a neutral pH. The very high availability of the K element can be antagonistic to the secondary macronutrient, namely Ca. As a result, the Ca^{2+} element will be retained and replaced by K^+ ions, resulting in low Ca availability. Ca plays a very important role at the root growth point. Ca deficiency causes stunted root formation and growth (Muchlis, 2017). Inhibition of root growth results in low plant water and nutrient absorption (Kurniawan et al., 2017), so that plant fresh weight is low or not significantly different between treatments.

Conclusion

Based on the research results, it can be concluded that:

1. There was no interaction between the dose of Phosphate Solubilizing Bacteria (PSB isolate and various types of manure (cow, goat, and laying hen) in increasing the growth and yield of bok choy (*Brassica rapa* L.) plants on post-rock excavation soil.
2. The dose of PSB isolates and various types of manure had not been able yet to increase the growth and yield of bok choy (*Brassica rapa* L.) plants on post-rock excavation soil mainly due to the soil natures.

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