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Optimizing Entisols properties and enhancing melon (*Cucumis melo* L.) yields using biofilm biofertilizer, organic matter, and NPK fertilization

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ABSTRACT

Entisols have significant agricultural potential but also limitation by a high sand fraction and unstable soil aggregates, leading to low nutrient levels and poor water-holding capacity. This study aims to determine the optimal combination of biofilm biofertilizer, organic matter, and NPK fertilizer to improve it soil properties and enhance melon yields (*Cucumis melo* L.). A completely randomized block design was employed, consisting of three treatment factors: biofilm biofertilizer (BiO2) formulation (without BiO2, formula 1, and formula 2), organic matter dosages (0, 1.25, and 2.5 kg plant^{-1}), and NPK dosages (0%, 50%, and 100% of the recommended dosage). The variables observed included soil properties (bulk density, aggregate stability, soil organic carbon (SOC), and available phosphorus), melon growth and yield. Data was analyzed using ANOVA at a 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) if any significant effects. The results showed that the interaction among BiO2, organic matter, and NPK significantly affected soil properties, enabling a reduction in NPK applications by up to 50% when combined with BiO2 and organic matter. The application of 2.5 kg plant^{-1} of organic matter outperformed 1.25 kg plant^{-1} in improving bulk density, aggregate stability, available-P, P-uptake, plant dry weight, and melon yields; however, significant differences between these doses were observed only for available P and P uptake. This study can serve as a reference for determining fertilizer dosages to increase melon yields while improving the soil properties of Entisols and expanding their agricultural use.

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1. INTRODUCTION

Melons are among the most popular fruits in Indonesia due to their sweet and refreshing taste. Melon (*Cucumis melo* L.) originates from Africa (Ginting et al., 2017) and belongs to the *Cucurbitaceae* family. Melon plants grow well at pH 6.0-6.8, though they can still produce at pH 5.6–7.2; however, productivity declines below pH 5.6. Melons can thrive in tropical and subtropical areas at altitudes ranging from 300-1.000 m above sea level (Ramadani, 2008). The optimal temperature for melon cultivation is approximately 25–30°C. Melon is one of the popular fruits in Indonesia and the demand has increased (Setiawan et al., 2025), but currently it's production unable to meet national demand (Safwandi et al., 2021). Melon production tends to decrease year to year i.e from 138,177 tons in 2020 to 129,147 tons in 2021, to 118,177 tons in 2022 and to 117,794 tons in 2023 (BPS, 2024).

Entisols soils are widely distributed in Java, Sumatra, and Nusa Tenggara, covering a total area of approximately 3 million hectares, or about 2.1% of Indonesia's land area (Hartati et al., 2019). This presents significant potential for agricultural extensification. However, Entisols face several constraints for cultivation. They are characterized by low fertility due to low organic matter content and a crumbly to granular structure, resulting in rapid water loss through percolation (Saifulloh & Suntari, 2022). Generally, Entisols

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have a sandy texture and low water-holding capacity (Siregar et al., 2023). The dominance of the sand fraction contributes to significant leaching and the loss of essential nutrients. Low levels of organic matter and high sand content result in limited nutrient availability, with very low nitrogen (0.02%), low phosphorus (81 ppm), very low potassium (0.09%), and very low magnesium (0.18 meq 100 g^{-1}) (Sukarman et al., 2022). Such conditions are unfavorable for melon cultivation, as the soil does not supply adequate nutrients. Melon plants require various nutrients, especially N, P, and K, for growth and production (Ginting et al., 2017). Limited organic matter and nutrients also constrain P availability, primarily due to significant phosphorus fixation that reduces solubility. Therefore, it is necessary to improve phosphorus levels through the addition of organic matter, such as cow manure (Fikdalillah et al., 2016). Cow manure increases soil microbial activity, thereby enhancing the decomposition of added organic matter and improving P availability (Amelia et al., 2022). Nitrogen in cow manure contributes to protein synthesis during cell division and expansion, ultimately increasing stem biomass (Bella et al., 2023).

The continuous application of inorganic fertilizers without the incorporation of organic amendments can cause nutrient imbalances, degrade soil structure, and diminish microbial diversity (Murnita & Taher, 2021). Chemical residues that are slow to decompose may lead to soil compaction and pollution of soil and water bodies, thereby reducing soil fertility (Santoni et al., 2023). Nitrogen fertilizers such as urea, ZA, ammonium sulfate, ~~KCl~~, and ZK can acidify soil (Abdilah et al., 2018) due to the release of H+ ions during the transformation of ammonium into nitrate via nitrification (Permana et al., 2018). Thus, there is a need for environmentally friendly fertilizers that support plant growth while enhancing soil fertility in the long term, such as biofilm biofertilizers.

Biofilm biofertilizer (BiO2) is a biofertilizer which microbial inoculant forms a thin layer of microbes *(microbial biofilm)* when applied to soil or plants. BiO2 contains numerous beneficial microorganisms, including nitrogen-fixing bacteria, phosphate-solubilizing bacteria and fungi, and potassium-solubilizing microorganisms. In addition to enhancing nutrient availability, these microbes ~~et~~ can inhibit the growth of *Fusarium*, the causative agent of basal rot disease (Sudadi et al., 2020). The application of 1000 ml ha^{-1} phosphate-solubilizing biofertilizer has been proven to improve aggregate stability and increase tomato fruit weight (Ahmad et al., 2019).

Exopolysaccharide-producing (EPS) bacteria, such as *Pseudomonas plecoglossicida, Azosprillium brasilense* (Sembiring et al., 2013), serve as adhesive agents that bind soil particles by forming polymer bridges, thereby enhancing the stability of soil aggregates (Roaidha et al., 2021). Phosphate-solubilizing microorganisms in biofilm biofertilizers also increase phosphorus fertilization efficiency by dissolving soil-bound inorganic P (Hartati et al., 2023). Phosphate-solubilizing bacteria produce phosphatase enzymes that mineralize organic phosphate and hydrolyze it into inorganic forms (Fitriatin et al., 2020).

The use of biofilm biofertilizers thus holds considerable potential to improve Entisols properties and enhance melon production. This study analyzed the effects of biofilm biofertilizer, organic matter, and NPK fertilizer on melon yields and the properties of Entisols soils from Colomadu, District. The biofilm biofertilizer used in this study contained diverse microorganisms capable of improving soil nutrient availability. Additionally, this study examined the relationships between soil properties and nutrient uptake by plants, which ultimately affect melon yield.

2. MATERIALS AND METHODS

This research was conducted from July to October 2023 at the Agricultural Field Laboratory, Faculty of Agriculture, Universitas Sebelas Maret, located in Bakaran, Sukosari Village, Jumantono District, Karanganyar Regency (7˚ 37'48,3" S, 110˚56'51.2" E), Central Java Province, Indonesia, at an altitude of 324 m above sea level. The soil used for the experiment was collected from *Balai Penyuluhan Pertanian* (Colomadu Agricultural Extension Center) (8˚ 28'6.3" S, 110˚ 46'5.7" E) and classified as Entisols. The initial soil characteristics are presented in Table 1.

Melon seeds from the F1 Pertiwi Hybrid variety were provided by Agri Makmur Pertiwi LLC. The organic matter used was cow manure and was sourced from the *Abdi Dalem* Farmers Group in Surakarta, while NPK Mutiara 16-16-16 fertilizer was obtained from *PT. Meroke Tetap Jaya*.

The biofilm biofertilizer consisted of two formulations: Formula 1 contained phosphate- and potassium-solubilizing bacteria, sulfur-oxidizing bacteria, nitrogen-fixing bacteria, and Trichoderma and Beauveria species as biocontrol agents against pests and diseases. The bacterial isolates had not yet been sequenced (Sudadi, Suryono, et al., 2021). Formula 2 contained 2 bacterial isolates and one fungal isolate that were sequenced and identified as *Pseodochrobactrum* sp. (a phosphorus-solubilizing and nitrogen-fixing bacterium), *Bacillus cereus* (a phosphorus- and potassium-solubilizing bacterium), and *Trametes polyzona* (an IAA-producing fungus). These microorganisms were isolated from melon rhizosphere and formulated as biofilm biofertilizer inoculum to enhance melon growth and yield. They can increase the availability of P, K and N nutrients as well as produce IAA, which promotes plant growth (Amalina, Sudadi, Pratama, & Dewi, 2023; Amalina, Sudadi, Pratama, Dewi, et al., 2023).

Table 1. Initial Entisols Soil Properties.

No.	Parameter	Mark	Unit	Classification
1	**Soil Texture**			
	Clay	23.24	%	Loam
	Silt	40.54	%	
	Sand	36.22	%	
2	Water Holding Capacity	3.38	%	
3	Soil bulk density	1.36	g cm^{-3}	
4	Aggregate Stability	39.59	-	Very Low
5	Organic Carbon (C-organic)	0.70	%	Very Low
6	Available Phosphorus	7.23	ppm	Low

Remarks: Classification according to Soil Research Institute (Eviati et al., 2023).

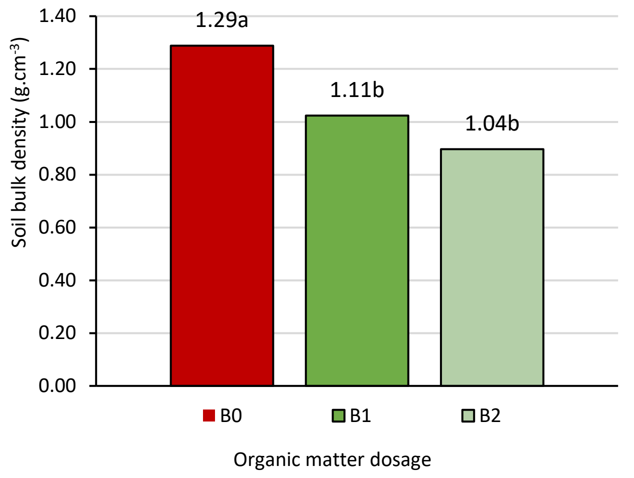

Figure 1. Effect of organic matter dosage on soil bulk density of Entisols cultivated with melon (*Cucumis melo* L.).

Formula 1 (liquid BiO2) was multiplied in a culture medium consisting of molasses, coconut water, and clean water in a ratio of 3:10:12. The isolates of Formula 2 were cultured on Nutrient Agar (NA) medium (28 g per liter) for the bacteria and Potato Dextrose Agar (PDA) medium (39 g per liter) for the fungus. They were incubated for one week before being propagated in the same liquid medium (molasses, coconut water, and water in a ratio of 3:10:12) for 48 hours.

The experiment used a factorial completely randomized block design, consisting of three treatment factors: biofilm biofertilizer formula (BiO2) (F), organic matter dosage (B), and NPK fertilizer dosage (P). The BiO2 formula had three treatment levels: without biofilm biofertilizer formula (BiO2) (F0), BiO2 formula 1 (F1), and BiO2 formula 2 (F2). The organic matter dosage factor had three levels: without organic matter (B0), 1.25 kg plant^{-1} (B1), and 2.5 kg plant^{-1} (B2). The NPK fertilizer dosage factor was also divided into three levels: without NPK fertilizer (P0), 50% of the recommended dosage (P1), and 100% of the recommended dosage (P2). Each treatment combination was repeated three times.

Organic matter was applied at the time of planting and thoroughly mixed with 8 kg of fine soil before filled in 10 liter volume pots (Krisdiyantoro et al., 2023). The recommended NPK fertilizer dosage used was 50 g per plant given 5 times i.e. 10 g per plant at planting, followed by four additional applications at 14, 24, 34, and 44 days after planting (DAP), each at 10 g per plant. A fifth application occurred at 54 DAP using KNO_3 at 5 g plant^{-1} (Huda and Suwarno (2023) with modification). This dosage was in accordance with Djibran et al. (2024). BiO2 was sprayed on plants and surrounding soil at 5 ml plant^{-1} twice a week for eight weeks.

Soil and plant samples for laboratory analysis were collected when the plants reached their maximum vegetative phase. The soil parameters analyzed included bulk density (lump method) and aggregate stability (double sieving method), following guidelines from the Center for Agricultural Land Resources Research and Development (Kurnia et al., 2022). Additionally, soil organic carbon content (Wakey & Black method), available phosphorus (Olsen), and plant phosphorus uptake (extract HNO_3 and $HClO_4$) were analysed according to the methods recommended by Soil Research Institute (Eviati et al., 2023).

Data were statistically processed using analysis of variance (ANOVA) at 95% confidence interval, followed by Duncan's Multiple Range Test (DMRT) to identify significant differences between treatments. Correlation tests were conducted to determine the strength and direction of the relationship among dependent variables (Purba & Purba, 2022).

3. RESULTS

3.1. Soil Bulk Density

The ANOVA test results indicated that only the organic matter treatment significantly affected soil bulk density ($P < 0.05$). As shown in Figure 1, soil bulk density decreased linearly with increasing organic matter dosages. The B2 treatment (2.5 kg organic matter plant^{-1}) resulted in a bulk density of 1.04 g cm^{-3}, representing a 19.37% reduction compared to the control. However, this result was not significantly different from the soil bulk density observed in the B1 treatment (1.25 kg organic matter plant^{-1}), which yielded a soil bulk density of 1.11 g cm^{-3}. This indicates that applying 1.25 kg organic matter per plant is sufficient to significantly reduce soil bulk density.

3.2. Soil Aggregate Stability

According to the ANOVA, only the organic matter dosage had a significant influence on soil aggregate stability ($P < 0.05$). Figure 2 shows that incorporating organic matter increased soil aggregate stability, with the B2 treatment (2.5 kg organic matter plant^{-1}) providing the highest values, although not significantly different from the B1 treatment (1.25 kg organic matter plant^{-1}). Similar to the effect on soil bulk density, applying 1.25 kg organic matter per plant appears more efficient than 2.5 kg per plant.

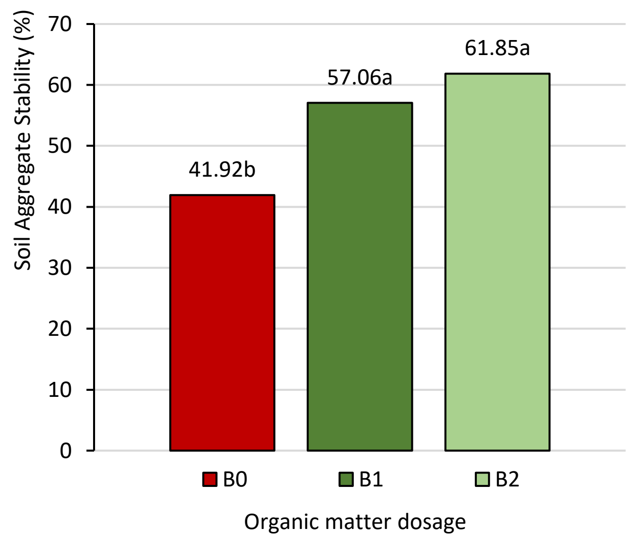

Figure 2. Effect of organic matter dosage on soil aggregate stability of Entisols cultivated with melon (*Cucumis melo* L.).

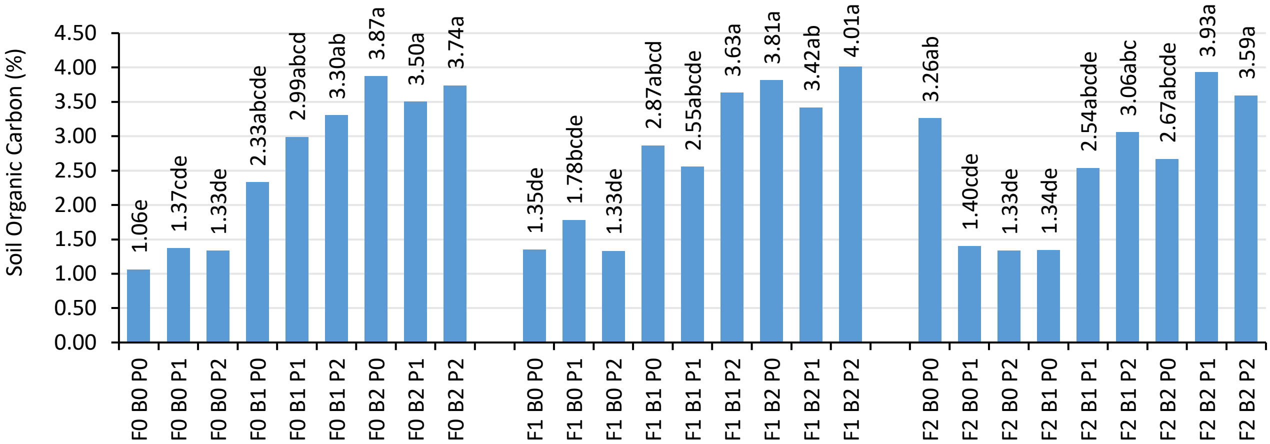

Figure 3. Interaction of BiO_2, organic matter, and NPK fertilizer dosage on soil organic carbon of Entisols cultivated with melon (*Cucumis melo* L.).

Table 2. Effect of Organic Matter and NPK Fertilizer on Available Phosphorus, Phosphorus Uptake, and Plant Dry Weight.

Treatments		Available-P (ppm)	P Uptake (%)	Plant Dry Weight (g)
Organic Matter Dosage	B0	7.97c	0.63c	17.55b
	B1	18.12b	0.71b	24.5a
	B2	24.78a	0.85a	27.95a
NPK Fertilizer Dosage	P0	12.72c	0.56c	17.7b
	P1	16.92b	0.81a	31.52a
	P2	21.23a	0.81b	20.79b

Remarks: Different letters within the same column and treatment indicate significant differences at P < 0.05.

3.3. Soil Organic Carbon (SOC)

The ANOVA results revealed that the interaction between BiO_2, organic matter dosage, and NPK dosage had a highly significant effect on SOC levels ($P < 0.01$). Figure 3 indicates that the best results were obtained with the F1B2P2 treatment (BiO_2 formula 1 + 2.5 kg organic matter plant^{-1}+ 100% NPK). There was a clear trend of increased soil organic carbon content with higher dosages of both organic matter and NPK fertilizer.

3.4. P Availability

The ANOVA results showed that both organic matter dosage and NPK dosage independently had significant effects on available phosphorus P ($P < 0.05$). Table 2 demonstrates an increase in available P increased in Entisols with higher dosages of organic matter and NPK fertilizer. Notably, organic matter produced better results than NPK fertilizer alone, with the highest available P observed in the B2 treatment (2.5 kg organic matter plant^{-1}).

3.5. P Uptake

The ANOVA results indicated that both organic matter dosage and NPK dosage independently had a significant effect on P uptake ($P < 0.05$). Table 2 shows that P uptake increased with higher dosages of organic matter and NPK fertilizer. The addition of organic matter resulted in higher P uptake compared to the NPK treatments alone, with the highest value recorded in the B2 treatment (2.5 kg organic matter plant^{-1}). P absorption tended to increase along with the increase of P availability in the soil.

3.6. Plant Dry Weight

The ANOVA analysis revealed that the application of organic matter and NPK fertilizer dosage significantly affected plant dry weight ($P < 0.05$). Table 2 illustrates that plant dry weight increased with higher organic matter dosages. The 2.5 kg plant^{-1} organic matter treatment produced the highest plant dry weight, although it was not significantly different from the 1.25 kg treatment. Plant dry weight increased with the use of 50% of the recommended NPK fertilizer dosage but decreased with the 100% dosage. Plant dry weight also tended to increase along with higher P absorption.

3.7. Fruit Weight

The ANOVA results indicated that the interaction between the BiO_2 formula and NPK fertilizer dosage, as well as the interaction between organic matter and NPK fertilizer dosage, significantly affected melon fruit weight ($P < 0.05$). The highest fruit weight was recorded in the F0P1 treatment (without BiO2 + 50% NPK fertilizer), followed by the B2P1 treatment (organic matter 2.5 kg plant^{-1} + 50% NPK) (Table 3).

Table 3. The Influence of BiO2 Formula, NPK Fertilizer Dosage and Organic Matter Dosage on melon Fruit Weight.

Combination Treatments		NPK Fertilizer Dosage		
		P0	P1	P2
		Fruit Weight (g)		
BiO_2 formula	F0	306.38 c	500.16 a	292.94 c
	F1	267.44 c	458.8 ab	295.93 c
	F2	336.67 c	341 c	272.78 c
Organic matter dosage	B0	135.03 d	436.67 a	192.64 cd
	B1	346.56 abc	380.13 ab	278.79 bcd
	B2	428.89 a	483.16 a	390.22 ab

Remarks: The number followed by different letters indicate significant differences at P < 0.05.

Table 4. Correlation Among Parameters.

	BD	Soil Aggregate	SOC	Available-P	P Uptake	Plant Dry Weight
Soil Aggregate	-0.412					
SOC	-0.411	0.456				
P-Availability	-0.448	0.405	0.581			
P uptake	-0.219	0.319	0.489	0.462		
Plant Dry Weight	-0.264	0.250	0.362	0.371	0.834	
Fruit Weight	-0.382	0.161	0.302	0.324	0.507	0.595

Remarks: 0% (not correlated), ≤25% (very weak), 26-50% (weak), 51-75% (strong), 76-99% (very strong), 100% (perfect) (Roflin et al., 2022).

3.8. Correlation of Each Parameter

Table 4 shows that SOC was strongly positively correlated with soil P availability and weakly positively correlated with P uptake and soil aggregate stability. P uptake is also strongly positively correlated with fruit weight and very strongly positively correlated with plant dry weight. Furthermore, plant dry weight was strongly positively correlated with fruit weight.

4. DISCUSSION

The interaction of organic matter and BiO_2, as well as the interaction of organic matter and NPK fertilizer, had a significant effect on melon fruit weight, with the highest results obtained in the F0P1 treatment, which achieved an average fruit weight of 500.16 g. This result was not significantly different from the B2P1 treatment, which yielded an average fruit weight of 483.16 g. The application of 50% of the recommended NPK dosage produced better results than the application of 100% dosage, which can be attributed to excessive fertilization leading to luxury consumption (Xia et al., 2019). Luxury consumption is the absorption of excess nutrients by plants that does not affect yield but only increases the concentration of nutrients in plants (Rosniawaty et al., 2021).

Excess fertilization also acidifies the soil (Abdilah et al., 2018) due to the conversion of ammonium to nitrate through nitrification, which releases H^+ ions and lowers soil pH (Permana et al., 2018). This reduces enzyme activity (Sawicka et al., 2020), and diminishes soil bacterial diversity and abundance (Muhammad et al., 2022). A soil pH near neutrality promotes more efficient nutrient exchange, resulting in optimal availability of nutrients, including phosphorus (P) (Suntoro et al., 2024).

The combined application of organic matter and NPK fertilizer increased fruit weight by improving nutrient availability in the soil. Cow manure contains various macro- and micronutrients, such as nitrogen, phosphorus, potassium, calcium, magnesium, and manganese, which are essential for plant growth (Kaho et al., 2020). Nitrogen plays a critical role in cell division and elongation, which increases leaf area and number. Phosphorus is involved in the formation of phospholipids, carbohydrates, and enzymes, while potassium supports growth by regulating photosynthate distribution, stomatal function, enzyme activation, carbon and nitrogen metabolism, and sugar transport (Xu et al., 2020). These processes promote carbohydrate accumulation in the fruit, thereby increasing yield (Al-Bayati, 2020).

The level of nutrient absorption can be reflected by plant dry weight, as supported by the positive correlation between dry weight and fruit weight (Table 4, r = 0.595). Dry weight is a useful indicator of plant nutritional status: higher dry weight indicates good growth and nutrient supply, while lower dry weight suggests nutrient deficiencies (Maulani, 2019). This relationship is further supported by the strong correlation between P uptake and stover dry weight (Table 4, r = 0.834). Fertilization increases nutrient availability and uptake in the rhizosphere, promoting biomass accumulation (Du et al., 2021). Nutrients in fertilizers stimulate protoplasm formation, accelerating cell division and elongation (Ariyanti & Aini, 2024).

Humic acids in organic matter interact with metal oxides (e.g., alumina, iron oxide, silicon dioxide, titanium dioxide) through complexation, chelation, and adsorption, thereby directly or indirectly influencing phosphate adsorption and P availability (Yang et al., 2019). P availability was also correlated with soil aggregate stability (r = 0.405) and SOC (r = 0.581). Soils with stable aggregates retain water and reduce nutrient leaching, while unstable aggregates diminish water and nutrient retention, leading to phosphorus losses (Pujawan et al., 2016). Additionally, SOC can limit phosphorus migration into micropores because its relatively large molecules coat the sorption surfaces, increasing long-term P availability (Hawkins et al., 2022).

The highest soil aggregate stability was obtained with the addition of organic matter at a dosage of 2.5 kg $plant^{-1}$. Organic matter provides carbon and nutrients that support the growth and reproduction of microorganisms, thereby improving soil aggregate stability (Liu et al., 2023). Microorganisms enhance aggregate formation through the production of exopolysaccharides (EPS) and hyphae that bind soil particles into larger aggregates (Ahmad et al., 2019). Exopolysaccharides are secreted by microorganisms (Ruijgrok et al., 2024) and consist of various sugars, either of the same or different types, that form complexes by associating with proteins, lipids, metal ions, extracellular DNA (eDNA), and other organic and inorganic compounds to create a protective layer around microbial colonies or biofilms. Glucosyltransferases (GT) assemble these sugars into monosaccharides or oligosaccharides, which are then further polymerized into polysaccharides prior to secretion onto the cell surface (Rana & Upadhyay, 2020).

The combination of 100% of the recommended dosage of organic matter and 50% of the recommended dosage of NPK fertilizer proved to be the most effective treatment, as it increased yields while improving Entisols soil properties. However, the effect of adding BiO2 was not clearly observed in this study, possibly because the microorganisms it contained did not function optimally maybe because the high NPK dosages used. Melon fruit weight increase with the increase of NPK dosage used to 50% of recommended dosage than decrease with the increase of NPK dosage to 100% (Table 3). Otherwise, both BiO2 formula have equal capability in increasing soil nutrient availability and to stimulate plant growth. This finding was not in accordance with the results reported by Amalina, Sudadi, Pratama and Dewi (2023), Amalina, Sudadi, Pratama, Dewi, et al. (2023), Sudadi et al. (2020), Sudadi, Suryono, et al. (2021), and Sudadi, Nurjanah, et al. (2021). Amalina, Sudadi, Pratama and Dewi (2023) and Amalina, Sudadi, Pratama, Dewi, et al. (2023) stated that biofilm biofertilizer inoculants isolated from *Cucumis melo* could increase available phosphorus and improve melon growth. In line with these findings, Sudadi, Nurjanah, et al. (2021) reported that the interaction between organic fertilizer dosage and biofilm biofertilizer (BiO2) significantly influenced nitrogen uptake in shallot cultivated on slightly acidic soil. The application of organic fertilizer decomposed with BiO2 increased total nitrogen, available phosphorus, exchangeable potassium, and kale (*Ipomoea reptans*) biomass (Sudadi et al., 2020), enhanced available phosphorus, phosphorus uptake, and shallot yield on Vertisols (Sudadi & Setyawan, 2021) and improved nitrogen, phosphorus, and potassium status and mustard growth on Lithosols (Sudadi, Suryono, et al., 2021).

The effectiveness of biofertilizers can be influenced by several factors, including competition with indigenous microorganisms that are better adapted, inoculum density (Querejeta et al., 2022), and soil conditions such as temperature, organic matter content, pH, aeration, and moisture (Putra et al.). According to climatological data from the Faculty of Agriculture, Universitas Sebelas Maret, daytime air temperatures reached 37°C during the study period, resulting in dry soils and reduced moisture levels that may have inhibited microbial activity. Further research should investigate whether providing shade for melon plants could help maintain soil moisture and enhance biofertilizer performance.

5. CONCLUSION

Organic matter treatment significantly affected soil bulk density while BiO2 formula and NPK fertilizer dosages were not. The combination of BiO_2, organic matter, and NPK fertilizer significantly improved SOC content and applying 1.25 kg plant^{-1} organic matter is sufficient to significantly reduce soil bulk density. Adding 2.5 kg plant^{-1} of organic matter enhances aggregate stability and phosphorus (P) availability, resulting in increased of plant dry weight. Soil organic carbon (SOC) was strongly correlated with soil available-P and weakly correlated with P uptake which is strongly correlated with plant dry weight and fruit weight. Notably, using 50% of the recommended NPK dosage improves P-availability and plant growth higher compared to 100% NPK. Overall, this approach allows for a 50% reduction in fertilizer used, promoting more sustainable agricultural practices while maximizing melon yield. The effect of BiO2 formula was not significant in this study, possibly because the microorganisms it contained did not function optimally, maybe caused by the high dosage of NPK fertilizer used, otherwise, the capability of the two BiO2 formula to increase nutrient availability and to stimulate plant growth were not significant different.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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