POPULATION OF P-SOLUBILIZER BACTERIA, AVAILABLE P, P UPTAKE AND CHILI YIELD AFFECTED BY BIOAMELIORANTS AND NUTRIENT

POPULASI BAKTERI PELARUT P, P-TERSEDIA, SERAPAN P DAN HASIL CABE YANG DIPENGARUHI OLEH BIOAMELIORAN DAN HARA

Betty Natalie Fitriatin[1*], Limbong Agatha Dita[2], Nicky Oktav Fauziah[3], Tualar Simarmata[1], Hanif Fakhrurroja[4]

[1] Department of Soil Sciences and Land Resouces Management, Agriculture Faculty, Universitas Padjadjaran–Jatinangor 45363-West Java–Indonesia
[2] Agrotechnology, Agriculture Faculty, Universitas Padjadjaran–Jatinangor 45363-West Java–Indonesia
[3] Agricultural Science Study Program, Agriculture Faculty, Universitas Padjadjaran–Jatinangor 45363-West Java–Indonesia
[4]National Research and Innovation Agency- BRIN
[4]Department of Plant Pest and Desease, Agriculture Faculty, Universitas Padjadjaran–Jatinangor 45363-West Java–Indonesia

* Correspondence: betty.natalie@unpad.ac.id

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ABSTRACT

The consumption of red chili (*Capsicum annum* L.) increased annually, requiring higher productivity. However, this is not supported by optimal soil fertility which has a low nutrient content. This research aimed to examine the interaction between bioameliorant dose (B) and nutrient solution application interval (F) on phosphate solubilizing bacteria (PSB), available P, P uptake, fruit weight per plant, and fruit weight per fruit. The research was conducted using a Factorial Randomized Block Design with two factors and three replications (bioamelioran dosage: 0, 3, 6 t ha^{-1}) and nutrient solution application interval: every one, three, and five days. The results showed an interaction effect on fruit weight with the best treatment being a bioameliorant dose of 3 t ha^{-1} and a nutrient solution interval once a day. The bioameliorant increased available P and the nutrient solution interval had influenced on soil available P and fruit weight per plant. Application of a bioameliorant dose of 3 t ha^{-1} and nutrient solution interval once a day produced the highest yield of chili.

Keywords : Amandement Soil, Beneficial Microbes, Nutrients, Red Chili

ABSTRAK

Konsumsi cabai merah (*Capsicum annum* L.) meningkat setiap tahunnya, sehingga membutuhkan produktivitas yang lebih tinggi. Namun, hal ini tidak didukung oleh kesuburan tanah yang optimal serta memiliki kandungan nutrisi yang rendah. Penelitian ini bertujuan untuk mengetahui interaksi antara dosis bioamelioran (B) dan interval pemberian larutan hara (F) terhadap bakteri pelarut fosfat (BPF), P-tersedia, serapan P, bobot buah per tanaman, dan bobot

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buah per buah. Penelitian dilakukan menggunakan Rancangan Acak Kelompok Faktorial dengan dua faktor dan tiga ulangan (dosis bioamelioran: 0, 3, 6 t ha^{-1}) dan interval pemberian larutan hara: setiap satu, tiga, dan lima hari. Hasil penelitian menunjukkan adanya pengaruh interaksi terhadap rerata berat buah, dengan perlakuan terbaik adalah dosis bioamelioran 3 t ha^{-1} dan interval pemberian larutan hara satu kali sehari. Pemberian bioamelioran mampu meningkatkan P-tersedia. Interval pemberian larutan hara mempengaruhi kandungan P-tersedia tanah dan bobot buah per tanaman. Aplikasi bioamelioran dengan 3 t ha^{-1} dan interval pemberian larutan hara satu kali sehari menghasilkan hasil cabai merah tertinggi.

Kata kunci: Cabai Merah, Mikroba Menguntungkan, Pembenah Tanah, Unsur Hara

INTRODUCTION

Red chili (*Capsicum annuum* L.) is a type of horticultural plant from the *Solanaceae* family. This red chili is economically valuable and also contains beneficial nutrients, including several vitamins such as vitamins A, C, and E, as well as carotenoids, which can act as anti-inflammatory and antioxidant agents (Bal et al., 2022). According to data from Badan Pusat Statistik (2024), the production of red chili in Indonesia in 2024 exhibited fluctuations. In July 2024, production output exceeded expectations by 66.711 tons; however, this figure represents a 33% decrease compared to June 2024 production levels. The sustained escalation in chili consumption annually underscores the imperative to augment red chili production to align with the prevailing demand.In chili cultivation, nutrient-related problems can significantly impact plant health, yield, and fruit quality.

Increasing the productivity and quality of chili plants can be achieved using a hydroponic system that employs nutrient solutions in plastic houses, with planting media such as cocopeat, rockwool, and husk charcoal. However, high production costs, including the cost of planting media, remain a limiting factor (Fauzi et al., 2024). The frequency of nutrient solution application in hydroponic systems, such as through drip irrigation, is quite intense, typically carried out 3-5 times a day (Thakur et al., 2023). As an alternative to reduce this frequency, soil media with the addition of ameliorants that can retain water and nutrients may be used. One potential medium is Inceptisol soil, although it has acidity issues that limit phosphorus availability (Patle et al., 2019). Ameliorants can help address soil acidity and increase the availability of essential nutrients for plants (Saputra & Sari, 2021).

Ameliorants are divided into three types, namely inorganic, organic, and biological or bioameliorant (Astikoe et al., 2023). Bioameliorant also increase organic matter content, bind Al and Fe, and reduce P fixation, thereby increasing available P and plant P uptake (Hanaf et al., 2020; Dubey et al., 2016). Bioameliorant can also increase the population of phosphate-solubilizing bacteria that play a role in plant metabolism, including root formation and fruit development (Timofeeva et al., 2022).

Application of bioameliorant with inorganic fertilizers, such as nutrient solutions, also increases soil bacterial populations and fertilizer effectiveness (Zhang et al., 2022). Providing the amount and frequency of nutrients will affect plant growth (Yunitasari et al., 2025). Microbes in bioameliorant utilize nutrients from nutrient solutions for growth and increase nutrient availability for plants (Dong et al., 2022). This research aims to examine the effect and interaction of bioameliorants and nutrient

solution application intervals in the cultivation of red chili plants on phosphate solubilizing bacteria populations, available P, P uptake and yield of red chili plants.

MATERIAL AND METHOD

The experiment was conducted from August 2023 to January 2024 at the Bale Tatanen Experimental Field, Faculty of Agriculture, Universitas Padjadjaran. The land elevation is ± 750 meters above sea level with Inceptisols soil order (pH 6.05; $C_{organic}$ 1.5%; N 0.23%; K 29.55 mg 100 g^{-1}; CEC 23.78 cmol kg^{-1}; and $P_{available}$ 1.035 mg 100 g^{-1}). This experiment used the Factorial Randomized Group Design method consisting of two treatment factors, namely the bioameliorant dosage factor consisting of three levels and the intensity of nutrient solution application consisting of three levels. There were nine treatment combinations of the two factors, and each combination was replicated three times, resulting in 27 experimental units. The treatments or factors to be tested in this experiment are as follows:

The first factor is the dose of bioameliorant (B):
b_0 = 0 t ha^{-1}
b_1 = 3 t ha^{-1}
b_2 = 6 t ha^{-1}
The second factor is the interval of nutrient solution application (F):
f_0 = applied once a day
f_1 = applied every three days
f_2 = applied every five days

Soil Preparation

The planting medium used is Inceptisols Jatinangor soil with a total mass of 10 kilograms per polybag. Before the chili seedlings are transferred, Trichoderma is given to the planting hole in each polybag as a base fertilizer and to prevent soil-borne diseases in chili plants. Chili seedlings are transferred into polybags that have been filled with planting media that is given water as much as 80% of the field capacity (Sihotang et al., 2024). Furthermore, the chili seedlings that have been transferred into the planting hole are covered with planting media and watered regularly every day.

Planting preparation

Nursery was conducted using Pilar 1 cultivar chili seeds, with seedling media composed of soil, cow dung manure, and husk charcoal in 1:2:1 ratio. Additionally, 2% of *Trichoderma* was added to the seedling media to prevent soil-borne diseases in chili plants. Once the chili seedlings reached 35 DAS (days after sowing) and had developed 4-5 leaves, the seedlings were transplanted.

Treatment Application

The bioameliorant was applied during the preparation of the planting media by mixing it with Jatinangor Inceptisols soil according to the treatment doses: 0 t ha^{-1} (0 g $plant^{-1}$), 3 t ha^{-1} (214.2 g $plant^{-1}$), and 6 t ha^{-1} (428.4 g $plant^{-1}$). The bioameliorant consisted of biochar (50%), sugarcane bagasse compost (25%), dolomite (10%), guano (10%), humic acid (2.5%), and biofertilizer containing *Azotobacter* sp. as nitrogen-fixing bacteria (1.25%) and *Pseudomonas* sp. As phosphate-solubilizing bacteria (1.25%). Each polybag contained a mixture of soil and bioameliorant weighing a total of 10 Kg. During the vegetative phase, the AB nutrient solution contains macro and micro nutrient (stock solution A containing $Ca(NO_3)_2$, KNO_3, Fe-EDTA, and stock solution B containing KH_2PO_4, $(NH_4)SO_4$, K_2SO_4(ZK), $MgSO_4.7H_2O$,

$CuSO_4$, $ZnSO_4$, H_3BO_3, $MnSO_4$, and Mo-NH_4) were applied as follows: at 1-2 weeks after planting (WAP) with a concentration of 800 ppm; at 3 WAP until the end of the vegetative phase with a concentration of 1.200 ppm. The third application was made at the onset of the generative phase, with a concentration of 1.600 ppm. The parameters observed were the population of phosphate solubilizing bacteria (CFU mL^{-1}) using the dilution method, available P (mg kg^{-1}) with Bray reagent, P uptake (mg/plant) analyzed by destruction method, fruit weight (g), and yield of chili (g).

RESULTS AND DISCUSSION

1. Population of phospate solubilizing bacteria

Observation data and analysis of variance at the 5% level showed that the bioameliorant treatment and nutrient solution interval had no interaction with the population of phosphate-solubilizing bacteria at 6 weeks after planting (WAP) (Table 1). This is thought to be due to the organic matter content in the bioameliorant, which is still too low to optimally increase the population of phosphate-solubilizing bacteria. This organic matter can provide nutrients and energy for soil microbes, including PSB, and can also serve as a habitat for PSB (Lai et al., 2022). The application of nutrient solutions has not optimally increased the PSB population, likely because the nutrients provided are sufficient for the plants, causing them to reduce the secretion of root exudates that serve as a carbon source for PSB, thereby inhibiting PSB growth (Upadhyay et al., 2022).

Based on Table 1, although there is no significant effect of nutrient solution application at intervals of once a day and every three days resulted potentially gave better to PSB population than other interval application. This can be attributed to the more frequent application of nutrient solutions, which are a type of inorganic fertilizer, leading to faster nutrient availability in the soil (Ma et al., 2023). The availability of various nutrients due to the application of inorganic fertilizers causes soil microbes, including PSB, to utilize these nutrients quickly as a source of energy for growth and metabolism (Kumar et al., 2022). This finding aligns with Dong et al. (2022), who stated that soil microbes utilize nutrients for growth, as many microbial metabolic processes require metal ion cofactors, such as manganese present in nutrient solutions.

Table 1. Effect of independent dosage of bioameliorant and interval of nutrient solution application on population of phosphate solubilizing bacteria at WAP

Treatment	Population of PSB (10^6 CFU.mL^{-1})
Bioameliorant	
0 t ha^{-1}	4.80 a
3 t ha^{-1}	4.83 a
6 t ha^{-1}	4.83 a
Nutrient Solution Interval Application	
once a day	5.24 a
every three days	4.78 a
every five days	4.43 a

Note: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% significance level.

Table 1 shown that there is no independent effect of each treatment, between bioameliorant treatment and nutrient solution interval, on the population of phosphate solubilizing bacteria (PSB).

Initial soil analysis showed a PSB population of 2.6×10^6 CFU mL^{-1}. Table 1 indicates that the bioameliorant dose treatment potentially increase the PSB population, likely because the bioameliorants used contain various organic materials such as coconut shell biochar, sugarcane blotong compost, and guano, which can serve as a nutrient source for PSB. The addition of organic matter can boost the PSB population as it increases the soil's C-organic content, which is essential for PSB (Djuuna et al., 2022).

2. Soil available P and plant P uptake

Initial soil analysis showed that the Inceptisols used before treatment had an available P content of 1.035 mg kg^{-1}, which is categorized as very low. Analysis of variance at the 5% level showed that bioameliorant treatment and nutrient solution intervals had no interaction effect on available P content. However, there were independent effects of each bioameliorant treatment and nutrient solution interval on soil available P content (Table 2). The absence of interaction may be due to the slow nutrient availability resulting from the application of bioameliorants, though these nutrients remain available for a long period (Baghdadi et al., 2018). Inorganic nutrient solutions provide nutrients quickly, including P nutrients, but only 10-30% are available to plants, while the rest is absorbed by colloids (Ibrahim et al., 2022). Continuous application of nutrient solutions might lead to more P nutrients being absorbed by colloids and becoming P-potential rather than available P. It is suspected that increasing the dose of bioameliorant may improve avaiable P.

Table 2 shown that the independent treatment of bioameliorant at a dose of 6 t ha^{-1} significantly differs from the control treatment. Application of the bioameliorant at this dose increased the available soil P content by up to 107.3%, although the increase was not significantly different from that observed with the 3 t ha^{-1} treatment.

Table 2. Effect of independent dosage of bioameliorant and interval of nutrient solution application on available P and P uptake at 6 WAP

Treatment	Available P (mg kg^{-1})	P Uptake (mg/plant)
Bioameliorant		
0 t ha^{-1}	8.06 a	0.54 a
3 t ha^{-1}	12.87 ab	0.81 a
6 t ha^{-1}	16.71 b	0.53 a
Nutrient Solution Interval Application		
once a day	21.85 b	0.95 a
every three days	8.52 a	0.52 a
every five days	7.25 a	0.42 a

Note: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% significance level

This increase in available P is attributed to the composition of bioameliorants, which includes blotong compost, guano, and bio-fertilizers containing phosphate solubilizing bacteria (PSB). Blotong compost can enhance available P content in the soil as it is organic matter that releases P nutrients absorbed by Al and Fe, making them available to plants (Ramadhani et al., 2022). Rohmad et al. (2024) stated that applying more guano fertilizer increases soil available P content because guano, being organic matter, produces organic acids such as fulvic and humic acids that bind Al and Fe, thus

making more available P. The addition of bio-fertilizer containing phosphate solubilizing bacteria helps increase available P content because PSB produces various organic acids that break bonds of P elements bound to Al and Fe in the soil (Pan & Chai, 2023).

Based on Table 2, the independent treatment of nutrient solution application at a daily interval showed significantly different results compared to intervals of once every three days and once every five days. Daily application of nutrient solutions increased the available P content compared to other treatments. This is likely because the nutrient solution contains various macro and micronutrients, including P nutrients, making them more available when applied daily. This finding aligns with Liu et al. (2024), who reported that more frequent nutrient solution applications result in higher nutrient availability compared to less frequent applications.

Observation data and analysis of variance at the 5% level showed that there was no interaction between the bioameliorant treatment and the nutrient solution interval on P uptake in chili plants. The absence of interaction is likely because the availability of P tends to be slow due to the application of bioameliorants, resulting in low P uptake by plants. Although the nutrient solution provides a small amount of available P, it further increases P potential (Ibrahim et al., 2022). It is suggested that the dose of bioameliorants needs to be increased to improve P availability for plants, thereby enhancing P uptake.

Table 2 shown that application of nutrient solution once a day gives the highest value of available P in the soil compared to application every three and five days. Table 2 shown that no significant independent effect of the nutrient solution and interval treatment, on plant P uptake.

3. Fruit weight

The results of observations and variance analysis at the 5% level showed an interaction between the dose of bioameliorant treatment and the interval of nutrient solution application on the fruit weight. Further tests showed that the optimal bioameliorant dose and nutrient solution interval for fruit weight were a bioameliorant dose of 3 t ha^{-1} and a nutrient solution interval of once a day (Table 3).

Table 3. Effect of dosage of bioameliorant and interval of nutrient solution application on fruit weight per weight

Treatment	Fruit Weight (g)		
	once a day	every three days	every five days
0 t ha^{-1}	11.63 a AB	12.94 b B	8.34 a A
3 t ha^{-1}	16.85 b B	8.02 a A	7.49 a A
6 t ha^{-1}	8.76 a A	8.74 a A	9.40 a A

Note: Numbers followed by different letters indicate significantly different mean values based on the Duncan test at a 5% significance level. Capital letters are read in the horizontal direction, comparing between two nutrient solution intervals on the same bioameliorant. Lowercase letters are read in the vertical direction, comparing between two bioameliorants at the same nutrient solution interval.

There is an interaction between the bioameliorant treatment and the nutrient solution application interval. Bioameliorants and nutrient solutions increase the availability of macro and micro nutrients essential for chili plants. This aligns with the

statement by Hariyono and Nugroho (2021), that the addition of nutrient solutions and bioameliorants increases the fruit weight per chili plant, as nutrient solutions provide various essential nutrients, especially potassium and phosphate, which are crucial during the generative phase of chili plants. Bioameliorants help improve soil quality and facilitate nutrient absorption in the soil with the aid of beneficial microbes present in bioameliorants. The addition of bioameliorants with inorganic fertilizers can increase nutrient availability for plants, improve soil productivity, and enhance nutrient retention, thereby increasing fertilizer efficiency (Asadu et al., 2024).

4. Yield of chili

Observation data and analysis of variance at the 5% level showed that there was no interaction between bioameliorant treatment and nutrient solution interval on fruit weight per plant. However, there was an independent effect of the nutrient solution interval treatment on the fruit weight of red chili plants (Table 4). The lack of interaction between bioameliorants and nutrient solution intervals is likely because the bioameliorant dose could be increased to have a greater effect on nutrient availability.

Table 4 shows that there is no independent effect of bioameliorant dosage treatment on the fruit weight per red chili plant. This is in line with the statement by Hartatik et al. (2023), which states that there is no significant effect of dolomite and guano ameliorants on fruit weight per plant because the doses of dolomite and guano added are too small to significantly increase nutrient availability in the soil, resulting in no increase in fruit weight per plant.

Table 4 also shows that there is an independent effect of the nutrient solution interval once a day on fruit weight per red chili plant. This is in line with the statement by Padmini et al. (2023), which suggests that the faster the interval of nutrient solution application, the higher the fruit weight per red chili plant, due to the quicker availability of macro and micro nutrients required by plants during the generative phase, which leads to an increase in fruit weight per red chili plant.

Table 4. Effect of independent dosage of bioameliorant and interval of nutrient solution application on yield per plant

Treatment	Yield per plant (g)
Bioameliorant	
0 t ha^{-1}	124.00 a
3 t ha^{-1}	103.17 a
6 t ha^{-1}	86.02 a
Nutrient Solution Interval Application	
once a day	148.43 b
every three days	93.03 a
every five days	71.72 a

Note: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% significance level

CONCLUSION

1. The results showed an interaction effect on fruit weight per fruit, with the best treatment being a bioameliorant dose of 3 t ha^{-1} and a nutrient solution interval once a day.
2. The bioameliorant increased available P and the nutrient solution interval had influenced on available P and fruit weight per plant.

3. A bioameliorant dose of 6 t ha^{-1} resulted in the highest available P. Applying the nutrient solution every day produced the highest available P.
4. The application of bioameliorant dose of 3 t ha^{-1} and the nutrient solution once a day produced the best fruit weight per fruit.

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REFERENCES

Asadu, C. O., Ezema, C. A., Ekwueme, B. N., Onu, C. E., Onoh, I. M., Adejoh, T., & Emmanuel, U. O. (2024). Enhanced efficiency fertilizers: Overview of production methods, materials used, nutrients release mechanisms, benefits and considerations. *Journal of Environmental Pollution and Management*. 1: 32-48. https://doi.org/10.1016/j.epm.2024.07.002.

Astiko, W., Ernawati, N. M. L., & Silawibawa, I. P. (2023). Impact of different soil tillage added bio-ameliorant on nutrient concentration and growth maize-soybean intercropping adaptive to climate change in dry land. *In E3S Web of Conferences* (Vol. 467, p. 01001). EDP Sciences.

Baghdadi, A., Halim, R. A., Ghasemzadeh, A., Ramlan, M. F., & Sakimin. S. Z. (2018). Impact of organic and inorganic fertilizers on the yield and quality of silage corn intercropped with soybean. *PeerJ* 6:e5280; DOI 10.7717/peerj.5280.

Bal, S., Sharangi, A. H., Upadhyay, T. K., Khan, F., Pandey, P., Siddiqui, S., & Yadav, D. K. (2022). Biomedical and antioxidant potentialities in chilli: Perspectives and way forward. *Molecules,* 27(19), 6380.

[BPS] Badan Pusat Statistik. (2024). Statistik Hortikultura 2024. Jakarta: Badan Pusat Statistik.

Djuuna, I. A. F., Prabawardani, S., Massora, M. (2022). Population Distribution of Phosphate-solubilizing Microorganisms in Agricultural Soil. *Microbes Environ*. 37(1):ME21041. doi: 10.1264/jsme2.ME21041. PMID: 35342122; PMCID: PMC8958300

Dong, H., Huang, L., Zhao, L., Zeng, Q., Liu, X., Sheng, Y. & Chen, H. (2022). A critical review of mineral–microbe interaction and co-evolution: mechanisms and applications. *National science review,* 9(10), nwac128.

Dubey, A. K., Devi, S., Pranjal, S. R., Yogesh, K., Ajay, K. V. & Sandip, K. C. (2016). Effect of NPK on plant growth, yield and quality of capsicum (*Capsicum annum* L.) under shade net condition. *International Journal of Current Microbiology and Applied Sciences*. 6(3): 1085-1091.

Fauzi, D., Isnaeni, A. S. & Nurhidayah S. (2024). The influence of nutrient concentration and hydroponic growing media on the growth and yield of pagoda mustard greens (*Brassica narinosa* L.). *Indonesian Journal of Agronomy*, 52(1), 122-129.

Hanaf, D., Anwar, S., Santosa, A. D., Nugroho, B., & Baskoro, D. P. (2020). Transformation of Aluminium Fractions and Phosphorus Availability in Acid Soils as The Result

of Microbes and Ameliorant Addition. *Journal of Degraded and Mining Lands Management,* 7(4), 2355-2362. https://doi.org/10.15243/jdmlm.

Hariyono, D., Ali, F. Y., & Nugroho, A. (2021). Increasing the growth and development of chili-pepper under three different shading condition in response to biofertilizers application. *Journal of Agricultural Science*, 43(1), 198-208.

Hartatik, W., Subiksa, I. G. M., Widowati, L. R., & Aksani, D. (2023). Effect of dolomite and micronutrients on the growth and yield of lowland rice on acid sulfate soil. *In E3S Web of Conferences* (Vol. 467, p. 01004). EDP Sciences.

Ibrahim, M., Iqbal, M., Tang, Y. T., Khan, S., Guan, D. X., & Li, G. (2022). Phosphorus mobilization in plant–soil environments and inspired strategies for managing phosphorus: A review. *Agronomy*, 12(10), 2539.

Kumar, S., Sindhu, S. S., & Kumar, R. (2022). Biofertilizers: An ecofriendly technology for nutrient recycling and environmental sustainability. *Current Research in Microbial Sciences*, 3, 100094.

Lai, W., Wu, Y., Zhang, C., Dilinuer, Y., Pasang, L., Lu, Y., Wang, Y., Chen, H., & Li, Z. (2022). Combination of Biochar and Phosphorus Solubilizing Bacteria to Improve the Stable Form of Toxic Metal Minerals and Microbial Abundance in Lead/Cadmium-Contaminated Soil. *Agronomy*, *12*(5), 1003. https://doi.org/10.3390/agronomy12051003

Liu, S., Qiang, X., Liu, H., Han, Q., Yi, P., Ning, H & Zhang, X. (2024). Effects of Nutrient Solution Application Rates on Yield, Quality, and Water–Fertilizer Use Efficiency on Greenhouse Tomatoes Using Grown-in Coir. *Plants*, *13*(6), 893.

Ma, G., Cheng, S., He, W., Dong, Y., Qi, S., Tu, N., & Tao, W. (2023). Effects of Organic and Inorganic Fertilizers on Soil Nutrient Conditions in Rice Fields with Varying Soil Fertility. *Land*, *12*(5), 1026. https://doi.org/10.3390/land12051026

Padmini, O. S., Brotodjojo, R. R., & Pratomo, A. H. (2023). Growth and Yield of Red Chili (*Capsicum Annuum* L.) as Responses to Various Interval and Frequency of Fertigation Application. In *BIO Web of Conferences* (Vol. 69, p. 01013). EDP Sciences.

Pan, L., & Cai, B. (2023). Phosphate-solubilizing bacteria: advances in their physiology, molecular mechanisms and microbial community effects. *Microorganisms*, *11*(12), 2904.

Patle, T., Khaddar, V. K., Tiwari, R., & Para, P. (2019). Evaluation of phosphorus availability and phosphorus fixation in four different soils orders. *Journal of Pharmacognosy and Phytochemistry* 8(2): 2087-2090

Ramadhani, P. F., Huda, H. F. N., Kusumawati, E., & Ghozali, M. (2022). The utilization of blotong, molases, bran, and coconut husk into compost using mol of stale rice and *Trichoderma* sp. *Jurnal Kimia Riset*, 7(1), 38–46. https://doi.org/10.20473/jkr.v7i1.35714

Rohmad, H. A., Thohiron, M., & Herawati, J. (2024). Study of Combination of Guano and Humic Acid Fertilizer on

Growth and Yield of Caisim Mustard Plants (*Brassica chinensis* Var. Parachinensis). *Journal of Applied Plant Technology*, 3(2), 120-129.

Saputra, R. A., & Sari, N. N. (2021). Ameliorant engineering to elevate soil pH, growth, and productivity of paddy on peat and tidal land. 1st International Conference on Sustainable Tropical Land Management IOP Conf. Series: *Earth and Environmental Science* 648 (2021) 012183 IOP Publishing doi:10.1088/17551315/648/1/012183.

Sihotang, T., Siregar, L. A. M., & Rahmawati, N. (2024). Growth and biochemical responses of red chili (*Capsicum annuum* L) under drought conditions with 6-Benzylaminopurine application. *International Journal of Basic and Applied Science*, *13*(2), 61-73.

Thakur, P., Wadhwa, H., & Kaushal, S. (2023). Nutrient Dynamics for Hydroponic Production System. *Int. J. Plant Soil Sci*.35 (21): 982-993.

Timofeeva, A., Galyamova, M., & Sedykh, S. (2022). Prospects for using phosphate-solubilizing microorganisms as natural fertilizers in agriculture. *Plants*, *11*(16), 2119.

Upadhyay, S. K., Srivastava, A. K., Rajput, V. D., Chauhan, P. K., Bhojiya, A. A., Jain, D., & Minkina, T. (2022). Root exudates: mechanistic insight of plant growth promoting rhizobacteria for sustainable crop production. *Frontiers in microbiology*, 13, 916488.

Yunitasari. Widiwurjani & Makhziah. (2025). Optimization of Concentration and Frequency of Liquid Organic Fertilizer Application on Cherry Tomato Plants (*Lycopersicum esculentum* var. Ruby) Growth and Yield. *Jurnal Agronomi Tanaman Tropika.* VOL. 7 NO. 1. https://doi.org/10.36378/juatika.v7i1.4049

Zhang, Q., Zhao, W., Zhou, Z., Huang, G., Wang, X., Han, Q., & Liu, G. (2022). The application of mixed organic and inorganic fertilizers drives soil nutrient and bacterial community changes in teak plantations. *Microorganisms*, *10* (5), 958.