THE INFLUENCE OF AMELIORANT, NUTRIENT SOLUTION AND BIOFERTILIZER ON SOIL P, PLANT P UPTAKE, AND YIELD OF RED CHILI

PENGARUH PEMBERIAN AMELIORAN, LARUTAN NUTRISI DAN PUPUK HAYATI TERHADAP P TANAH, SERAPAN P TANAMAN, DAN HASIL CABAI MERAH

Betty Natalie Fitriatin[1*], Putri Siska Ekayanti Dupa[2], Nicky Oktav Fauziah[3], Mui-Yun Wong[4], Tualar Simarmata[1]

[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] Department of Seed Technology, Politeknik Pembangunan Pertanian Yogyakarta-Magelang, Yogyakarta, Indonesia
[4] Department of Plant Protection, Faculty of Agriculture, Universiti Putra Malaysia, Sedang, Malaysia

*Corresponding author: betty.natalie@unpad.ac.id

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ABSTRACT

The productivity and quality of red chili are greatly influenced by soil conditions and the availability of nutrients. Nutrients play a critical role in the growth and development of red chili plants. This experiment aimed to determine the combination of ameliorant, nutrient solution, and biofertilizer on the population of phosphate-solubilizing bacteria (PSB), available P, P-uptake, and red chili production in Inceptisols. The experiment was conducted at the experimental field of the Faculty of Agriculture, Universitas Padjadjaran. The experiment used a Randomized Complete Block Design (RCBD) with seven treatments and four replications, consisting of control, NPK, and nutrient solution (NS) with doses of 0, 6, and 12 kg ha^{-1} biofertilizers. The dosage used in a single application was 15 g $plant^{-1}$ of NPK fertilizer and 300 mL $plant^{-1}$ of nutrient solution. The base fertilizer consisted of manure in the control treatment and an ameliorant in other treatments at a dose of 4 t ha^{-1}. The results showed that the combination of ameliorant + NPK + 6 kg ha^{-1} biofertilizer increased PSB population (4.93 x 10^6 CFU mL^{-1}), available P (15.4 ppm), and P-uptake (0.74 g $plant^{-1}$). Meanwhile, the combination of ameliorant + nutrient solution + 6 kg ha^{-1} biofertilizer increased fruit diameter (15 mm), and length of red chili (17.3 cm). Correlation analysis indicated positive correlation between red chili production with stem diameter and fruit length, but a negative correlation with P-uptake. Regression analysis indicated that stem diameter and PSB population had the most dominant effect on red chili yield.

Keywords: Correlation, NPK Fertilizer, P-available, Phosphate-Solubilizing Bacteria

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ABSTRAK

Produktivitas dan kualitas cabai merah sangat dipengaruhi oleh kondisi tanah dan ketersediaan unsur hara. Unsur hara memegang peranan penting dalam pertumbuhan dan perkembangan tanaman cabai merah. Percobaan ini bertujuan untuk mengetahui kombinasi amelioran, larutan hara dan biofertilizer terhadap populasi bakteri pelarut fosfat (BPF), P tersedia, serapan P, dan produksi cabai merah pada tanah Inceptisols. Percobaan dilaksanakan di lahan percobaan Fakultas Pertanian Universitas Padjadjaran. Percobaan menggunakan Rancangan Acak Kelompok Lengkap (RAKL) dengan tujuh perlakuan dan empat kali ulangan, terdiri dari: kontrol, NPK dan Larutan Hara dengan dosis 0, 6, dan 12 kg ha^{-1} pupuk hayati. Dosis yang digunakan dalam satu kali aplikasi adalah pupuk NPK 15 g tanaman^{-1} dan larutan hara 300 mL tanaman^{-1}. Pupuk dasar berupa pupuk kandang pada perlakuan kontrol dan amelioran pada perlakuan lain dengan dosis 4 t ha^{-1}. Hasil penelitian menunjukkan bahwa kombinasi amelioran + NPK + 6 kg ha^{-1} pupuk hayati mampu meningkatkan populasi BPF (4,93 x 106 CFU mL^{-1}), P tersedia (15,4 ppm), dan serapan P (0,74 g tanaman^{-1}). Sementara itu, kombinasi amelioran + larutan hara + 6 kg ha^{-1} pupuk hayati mampu meningkatkan diameter buah (15 mm), dan panjang cabai merah (17,3 cm). Analisis korelasi menunjukkan korelasi positif antara produksi cabai merah dengan diameter batang dan panjang buah, tetapi korelasi negatif dengan serapan P. Analisis regresi menunjukkan bahwa diameter batang dan populasi BPF memiliki pengaruh paling dominan terhadap hasil cabai merah.

Kata kunci: Bakteri Pelarut Fosfat, Korelasi, Pupuk NPK, P-tersedia

INTRODUCTION

Chili is a horticultural crop that is widely cultivated by farmers in Indonesia. Demand for chilies will continue to increase along with the increase in population, industrial development that requires chilies as a raw material, and the national economy. The national chili productivity level in 2019 has reached 8.62 t ha^{-1}. Meanwhile, the potential for chili production can exceed 10 t ha^{-1} (Center for Agricultural Data and Information Systems, 2020). Based on this data, increasing chili productivity is needed to maximize the potential for chili production in Indonesia. One effort that can be made is to increase productivity on agricultural land used for cultivating red chili plants.

Inceptisols are one of the soil orders that are widespread in Indonesia. The use of Inceptisols as land for cultivating plants has problems with acidic soil pH, low to medium nutrient content, and organic matter content (Muslim et al., 2020). The fertility of Inceptisols, which is still relatively low, can be improved with appropriate handling and technology, one of which is by adding nutrients to the soil.

In hydroponic systems, several research results reveal that the use of optimal nutrient solutions can increase plant growth and speed up harvest time (Rajaseger et al., 2023). However, research explaining the effect of providing nutrient solutions on the cultivation of plants grown on land is still limited. Based on previous research, giving nutrient solutions to red chili plants will be carried out by increasing the concentration every week to the recommended dose (700 – 1,300 ppm). Inceptisols also have other soil problems, namely acidic soil pH. Soil with a low pH is generally a limiting factor for plant growth due to the low availability of important nutrients such as phosphorus (P) (Getaneh

& Kidanemariam, 2021). The use of ameliorant can reduce soil acidity, increase soil organic matter, bind Aluminum (Al) and Iron (Fe) compounds so that they do not poison plants, and reduce P fixation so that it becomes available (Hanafi et al., 2020). The results of research by Situmorang et al. (2019), stated that using an ameliorant dose of 4 t ha^{-1} can have an effect on increasing organic C, soil pH, the population of the best phosphate solubilizing bacteria and increasing the yield of chili plants by 44.9%.

Fertilization activities can also be carried out to overcome the problem of lack of important nutrients in acid soil. One fertilizer that is often used is NPK fertilizer. Providing a single inorganic NPK fertilizer treatment can have a significant effect on red chili production (Anatalia et al., 2021). The results of research by Prastia (2017) state that application of NPK fertilizer at a dose of 15 g $plant^{-1}$ can provide the best results for the harvest of red chili plants with an average fruit weight of 300 g $plant^{-1}$. However, continuous use of inorganic fertilizers at relatively high doses can have a negative impact on the soil, thereby reducing agricultural land productivity.

Biofertilizers have several abilities, one of which is that they can dissolve phosphate in the soil from an unavailable form to a form available to plants. The availability of P elements in the soil can be helped by the microorganisms, especially phosphate solubilizing bacteria (PSB). The biofertilizer plays a role in dissolving bound P elements into a form available for plants by secreting organic acids (Alori et al., 2017).

The application of biofertilizers can increase plant productivity by increasing nutrient absorption and resistance to disease. Plants that receive sufficient nutrition and protection from biofertilizers tend to produce higher yields compared to plants without biofertilizers (Youssef, 2016). In the product recommendations, the dose of biological fertilizer that can be used for vegetable plants such as chili plants is 6 – 12 kg ha^{-1}. It is necessary to further study efforts to increase the yield of red chili plants on inceptisol. The aim of the experiment carried out was to study the effect of a combination of ameliorant, NPK fertilizer, and nutrient solution with biofertilizer on the population of phosphate solubilizing bacteria, available P, P uptake, and red chili production.

MATERIALS AND METHODS

This pot experiment was carried out in the experimental field of the Faculty of Agriculture, Universitas Padjadjaran, which is at an altitude of ± 752 meters above sea level. The soil used in this experiment was Inceptisols order from Jatinangor (soil acidity was slightly acidic with pH: 5.83; low soil P-available 1.23 ppm; soil C-organic 1.66% was low).

The ameliorant used in this research consisted of a mixture of 40% coconut shell biochar, 35% filter cake compost, 15% dolomite, and 10% guano. Inorganic fertilizer in the form of NPK and a nutrient solution consisting of macro and micronutrients. The plant used the large red chili seeds of the Baja F1 variety. Biofertilizer used contains a consortium of *Pseudomonas* sp., *Azotobacter* sp., and. *Azospirillum* sp.

The experiment was carried out using a Randomized Block Design consisting of seven treatments and four replications. consisted of: control, NPK, and nutrient solution with doses of 0, 6, and 12 kg ha^{-1} biofertilizers (BF). The dosage used in a single application was 15 g plant^{-1} of NPK fertilizer and 300 mL plant^{-1} of nutrient solution (NS). The base fertilizer consisted of manure in the control ameliorant in other treatments at a dose of 4 t ha^{-1}.

The response variables observed include: (1) population of phosphate solubilizing bacteria (PSB) by total plate count method, (2) soil P-available with the Olsen and Bray I method, (3) P uptake using the wet ashing method, (4) Chili production red in the form of plant growth parameters (stem diameter (mm) which are measured every week from 1 to 5 week after the plant (WAP) as well as plant yield parameters (fruit diameter (mm) and fruit length (cm)) which are measured at harvest, (5) Correlation and regression red chili yield with a population of PSB, P-available, P uptake, and red chili production.

ANOVA analysis of variance test was carried out to determine significance at the 5% real level. If the results have a significant effect, then the test is continued with a further DMRT test at a real level of 5% to determine the difference in effect between treatments. Correlation analysis was carried out using the Pearson correlation test method. Meanwhile, regression analysis was carried out using the stepwise method.

RESULTS AND DISCUSSION

PSB population

The results of statistical tests show that there is a real effect of treatment on the PSB population which is presented in Table 1. The results of analysis of variance at the 5% level of significance showed that giving ameliorant + NPK + 6 kg ha^{-1} biofertilizers gives a population of phosphate solubilizing bacteria of 4,93 x 10^6 CFU mL^{-1}. This treatment was significantly different from the control treatment and increased by 190% compared to the control and 152.8% compared to the initial soil analysis (1.95 x 10^6 CFU mL^{-1}) but not significant from other treatments. This is because applying biofertilizer to the soil can increase the microbial population.

Biofertilizers contain many microbes, one of which is phosphate-solubilizing bacteria. The population density of phosphate-solubilizing bacteria and their high effectiveness result in microbes being able to adapt to the environment and compete with Indigenous microbes in the soil (Janati et al., 2023). This is in line with research by Fitriatin et al. (2017), that the addition of phosphate biofertilizer with P fertilizer can increase the population of phosphate-solubilizing bacteria in the soil.

Coconut shell biochar in ameliorant given to the soil can also increase the activity and population of soil microorganisms. The high organic C content in biochar can be used as a food source or energy source and improve the living environment for microorganisms so that ameliorants containing biochar are given in the soil can influence the population of soil microorganisms (Situmorang et al., 2019). Apart from that, biochar also has the ability to maintain a more neutral soil pH range, so that it can be favorable for the growth of soil microorganisms (Khan et al., 2024).

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Table 1. Population of phosphate solubilizing bacteria in Inceptisols at the end of the vegetative period

Treatments	PSB population (10^6 CFU.g^{-1})	Percentage Improvement with Control (%)
Control (NPK + cow manure)	1.70 a	-
Ameliorant + NS + 0 kg ha^{-1} BF	3.00 abc	76.4
Ameliorant + NS + 6 kg ha^{-1} BF	3.71 bc	118.2
Ameliorant + NS + 12 kg ha^{-1} BF	4.26 bc	150.5
Ameliorant + NPK + 0 kg ha^{-1} BF	3.75 bc	120.5
Ameliorant + NPK+ 6 kg ha^{-1} BF	4.93 c	190.0
Ameliorant + NPK + 12 kg ha^{-1} BF	3.99 bc	134.7

Note: The average number followed by the same letter in each column indicates that it is not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

Soil P-Available

Based on data in Table 2 showed that giving of biofertilizer increased soil P-available. The results of analysis of variance at a significance level of 5% showed that the application of ameliorant + NPK + 6 kg ha^{-1} biofertilizers gives P-available results of 15 .4 ppm (Table 2). This treatment was significantly different from the control treatment and increased by 75% compared to the control treatment (8.8 ppm). This is caused by the influence of adding ameliorant as a basic fertilizer, biofertilizer which contains phosphate solubilizing bacteria, and the addition of P fertilizer so that it is able to provide phosphorus nutrients in the soil. Furthermore, the addition of NPK generally increased available P more than nutrient solutions.

Table 2. Soil P-Available in Inceptisols at the end of vegetative period

Treatments	Soil P-Available (ppm)	Percentage Improvement with Control (%)
Control (NPK + cow manure)	8.8 a	-
Ameliorant + NS + 0 kg ha^{-1} BF	11.8 b	34.0
Ameliorant + NS + 6 kg ha^{-1} BF	12.3 b	39.7
Ameliorant + NS + 12 kg ha^{-1} BF	13.2 bc	50.0
Ameliorant + NPK + 0 kg ha^{-1} BF	14.4 cd	63.6
Ameliorant + NPK+ 6 kg ha^{-1} BF	15.4 d	75.0
Ameliorant + NPK + 12 kg ha^{-1} BF	11.5 b	30.6

Note: The average number followed by the same letter in each column indicates that it is not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

The availability of P nutrients in the soil increases due to the activity of phosphate solubilizing bacteria which comes from the addition of biological fertilizer in the soil.

The mechanism of phosphate solubilization by phosphate solubilizing bacteria is associated with its ability to produce organic acids such as acetate, glutamate, glyoxalate, malate, propionate, glycolate, oxalate, succinate, citrate, and lactic. These organic acids are able to form chelates that bind to phosphate so that the H_2PO^- ion becomes free from its bonds and is available to plants (Hartati et al., 2023). Apart from that, PSB is also able to produce phosphatase enzymes in soil with low P content. Phosphatase enzymes can help dissolve organic phosphate into inorganic phosphate through a mineralization process so that P elements can be available in the soil (Sonia & Setiawati, 2022).

The ingredients in the ameliorant added in this treatment also contain dolomite. Dolomite is widely used as a liming material to neutralize or increase the pH of acidic soil. In acid soil, the availability of P in the soil is also very low. The addition of ameliorant containing dolomite can increase the availability of soil P elements as a result of freeing P from Al-P and Fe-P bonds. Apart from that, dolomite also aims to reduce the risk of Fe, Mn, and Al poisoning in the soil (Vondráčková et al., 2013). The increase in P-available in the soil is also caused by the direct effect of adding P fertilizer. Fertilizing with P fertilizer can increase the level of P-available in the soil or through the release of P from the adsorption complex. This is in line with the results of research by Dube & Chimdi (2021), that the influence of P fertilizer on the availability of P in the soil makes a significant difference

Plant P Uptake

The combination of ameliorant + NS + 6 kg ha^{-1} biofertilizer gave plant P uptake results of 0.74 g $plant^{-1}$ (Table 3). This treatment was significantly different from the control treatment. The P uptake of red chili plants in this treatment increased by 131.2% compared to the control treatment. This is related to the availability of phosphorus nutrients in the soil due to the influence of adding biological fertilizer and P fertilizer so that the P nutrient can be properly absorbed by plants.

Table 3. Plant P uptake at the end of vegetative period

Treatments	P Uptake (g/plant)	Percentage Improvement with Control (%)
Control (NPK + cow manure)	0.32 a	-
Ameliorant + NS + 0 kg ha^{-1} BF	0.48 ab	50.0
Ameliorant + NS + 6 kg ha^{-1} BF	0.63 bc	96.8
Ameliorant + NS + 12 kg ha^{-1} BF	0.51 ab	59.3
Ameliorant + NPK + 0 kg ha^{-1} BF	0.46 ab	43.7
Ameliorant + NPK+ 6 kg ha^{-1} BF	0.74 c	131.2
Ameliorant + NPK + 12 kg ha^{-1} BF	0.66 bc	106.2

Note: The average number followed by the same letter in each column indicates that it is not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

Providing biofertilizer and P fertilizer can increase plant P uptake due to increased P-availability in the soil. This is in line with the research results of Nadeem et al. (2022), that with increasing P-available in the soil and the lengthening of plant roots, diffusional contact between plant roots and P nutrients in the soil becomes greater, so that more P can be absorbed by plants. An important factor in the absorption of P nutrients by plants is soil water content. This is because most of the P is absorbed through the diffusion process by plants. The decrease in nutrient uptake is caused by a decrease in soil water content, thereby reducing the amount of nutrients that diffuse from the soil matrix to the root absorption surface (Yan et al., 2020).

Growth and Yield of Red Chili

The average stem diameter at 1 WAP was 2.52 mm, and this figure increased at 5 WAP to reach an average of 6.11 mm (Table 4). The results of observations of stem diameter in the ameliorant + NS + 6 kg ha^{-1} biofertilizers treatment at 5 WAP were 7.7 mm. This treatment was significantly different from the control treatment and was able to increase plant stem diameter at 5 WAP by 30.5% compared to the control treatment.

Table 4. Stem diameter of Red Chili influenced by the application of ameliorant, NPK, and biofertilizer

	Stem Diameter (mm)				
Treatments	1 WAP*	2 WAP	3 WAP	4 WAP	5 WAP
Control (NPK + cow manure)	2.8 c	3.2 b	4.3 b	5.1 bcd	5.9 b
Ameliorant + NS + 0 kg ha^{-1} BF	2.6 bc	3.3 bc	4.2 b	4.9 bc	6.9 cd
Ameliorant + NS + 6 kg ha^{-1} BF	2.7 c	3.6 c	5.2 c	6.9 e	7.7 d
Ameliorant + NS + 12 kg ha^{-1} BF	2.2 a	3.4 bc	4.0 b	5.7 d	6.9 cd
Ameliorant + NPK + 0 kg ha^{-1} BF	2.5 abc	3.3 bc	4.2 b	5.6 cd	6.3 bc
Ameliorant + NPK+ 6 kg ha^{-1} BF	2.6 c	3.0 b	3.9 b	4.5 b	5.4 b
Ameliorant + NPK + 12 kg ha^{-1} BF	2.3 ab	2.6 a	3.0 a	3.3 a	3.7 a

Note: The average number followed by the same letter in each column indicates that it is not significantly different based on Duncan's Multiple Range Test at the 5% significance level. *WAP: week after planting

Providing ameliorant + NS + 6 kg ha^{-1} biofertilizer was able to increase the yield parameters of red chili fruit in the form of diameter and length of red chili fruit (Table 5). This treatment resulted in a chili fruit diameter of 15 mm. The diameter of red chili fruit in this treatment was significantly different from the control treatment and increased by 16.2% compared to the control treatment. Apart from that, the results of observations of the length of chili fruit in the same treatment were 17.3 cm. The length of the chili fruit in this treatment was also significantly different from the control treatment and increased by 4.25% compared to the control treatment.

The addition of nutrients with a nutrient solution that contains complete nutrients, namely macro and micronutrients, supports plant growth and development. The microorganism content in the added biological fertilizer can also help in providing the nutrients needed for fruit growth, such as the element P, so that it has a good influence on fruit diameter and fruit length (Melini et al., 2023). The result of a large stem diameter can increase the number of leaves on the plant. Then, the large amount of photosynthate formed due to the large number of leaves can influence plant yields such as fruit diameter and length (Damayanti et al., 2022). Apart from that, the treatment given has also achieved a good balance for the growth and development of chili plants. This can be seen in other treatments which give lower results compared to the treatment of giving ameliorant + NS + 6 kg ha^{-1} biofertilizers.

Table 5. Yield of Red Chili influenced by the application of ameliorant, NPK, and biofertilizer

Treatments	Fruit Diameter (mm)	Percentage Increasing with Control (%)	fruit length (cm)	Percentage Increasing with Control (%) (%)
Control (NPK + cow manure)	12.9 a	0.0	16.6 ab	0.0
Ameliorant + NS + 0 kg ha^{-1} BF	13.7 ab	6.2	16.4 ab	-1.2
Ameliorant + NS + 6 kg ha^{-1} BF	15.0 c	16.2	17.3 b	4.2
Ameliorant + NS + 12 kg ha^{-1} BF	14.3 bc	10.8	17.1 b	6.6
Ameliorant + NPK + 0 kg ha^{-1} BF	14.4 bc	11.6	17.2 b	3.6
Ameliorant + NPK+ 6 kg ha^{-1} BF	14.3 bc	10.8	16.7 b	0.6
Ameliorant + NPK + 12 kg ha^{-1} BF	13.0 a	0.7	15.3 a	-7.8

Note: The average number followed by the same letter in each column indicates that it is not significantly different based on Duncan's Multiple Range Test at the 5% significance level

Correlation between Red Chili Yields and response variables

Correlation analysis using red chili yield t ha^{-1} on population parameters PSB, available P, P uptake, and red chili production. The results of analysis using the Pearson correlation test show that there is a relationship between the yield of red chilies t ha^{-1} with P uptake and red chili production. Table 6 shows that the Pearson correlation test analysis is presented in Table 6. Based on this, the relationship between red chili yield and P uptake is in the negative correlation category with a moderate relationship (r = 0.410), red chili yield with a stem diameter of 5 WAP is in the positive correlation category with a strong relationship (r=0.800), and the yield of red chilies with fruit length is in the positive correlation category with a moderate relationship (r=0.476). Meanwhile, red chili yield was not correlated with PSB population, P-available, and fruit diameter.

The relationship between crop yield and P uptake is negatively correlated. This means that the higher the crop yield, the lower the P uptake, or the higher the P uptake, the lower the crop yield. Phosphorus is a nutrient that can accelerate the growth of flowers and fruit. Therefore, the nutrient P is very necessary for red chili production (Putriani et al., 2022). However, the use of various types of nutrients in plants can have an impact on the yield of red chili plants. The efficiency of phosphorus absorption can be reduced if other nutrients such as nitrogen and potassium are more abundant than phosphorus, which can affect the yield of chili plants (Islam et al., 2018).

Table 6. Significance of Correlation of Red Chili Yields and Response Variables

Variable respond	PSB population	P-available	P uptake	Stem diameter 5 MST	Fruit diameter	Fruit length
Yield (ton.ha^{-1})	-0.297*	-0.218*	-0.410**	0.800***	0.339*	0.476****

Note: *) Not correlated; **) Medium negative correlation; ***) Strong positive correlation; ****) Medium positive correlation based on the Pearson correlation test.

The correlation between red chili yield with a stem diameter of 5 WAP and fruit length has a positive correlation. This means that increasing the stem diameter by 5 WAP and fruit length will have an impact on increasing plant yields. A larger stem diameter indicates better and stronger plant growth. Plants with a large stem diameter are able to support a more efficient photosynthesis process, thus affecting fruit growth and development such as fruit length. The more efficient the photosynthesis process, the greater the potential yield of red chilies. Apart from that, the availability of good nutrients can also support the growth and development of red chili plants. Adequate availability of nutrients such as nitrogen, phosphorus, and potassium can increase red chili yields (Rofidah et al., 2018).

CONCLUSION

Based on the results of the experiment it can be concluded as described below.

1. The combination of ameliorant + NPK + 6 kg ha^{-1} biofertilizer increased PSB population (4.93 x 106 CFU mL^{-1}), available P (15.4 ppm), and P-uptake (0.74 g plant^{-1}).
2. The combination of ameliorant + nutrient solution + 6 kg ha^{-1} biofertilizer increased fruit diameter (15 mm), and length of red chili (17.3 cm).
3. Correlation analysis indicated positive correlation between red chili production with stem diameter and fruit length, but a negative correlation with P-uptake.
4. Regression analysis indicated that stem diameter and PSB population had the most dominant effect on red chili yield.

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References

Alori, E. T., Glick, B. R., & Babalola, O. O. (2017). Microbial phosphorus solubilization and its potential for use in sustainable agriculture. *Frontiers in Microbiology*, *8*(June), 1–8. https://doi.org/10.3389/fmicb.2017.00971

Anatalia, R., Harsono, P., Yunindanova, M. B., & Purnomo, D. (2021). Effect of NPK fertilizer and foliar fertilizer on chili growth and yield. *Agrotechnology Research Journal*, *6*(2), 73–79.

https://doi.org/10.20961/agrotechresj.v6i2.54540

Center for Agricultural Data and Information Systems. (2020). *Outlook cabai komoditas pertanian sub sektor hortikultura*.

Damayanti, N. L. P. S. D., Udayana, I. G. B., & Situmeang, Y. P. (2022). Arabica coffee plant response to atonic concentration and production pruning. *SEAS (Sustainable Environment Agricultural Science)*, *6*(1), 10–15. https://doi.org/10.22225/seas.6.1.4881.10-15

Dube, B., & Chimdi, A. (2021). Effects of phosphorus fertilizer rates and its placement methods on residual soil phosphorus, yield, and phosphorus uptake of maize: at bedele district, ethiopia. *American Journal of Agriculture and Forestry*, *9*(5), 319–333. https://doi.org/10.11648/j.ajaf.20210905.16

Fitriatin, B. N., Suryatmana, P., Yuniarti, A., & Istifadah, N. (2017). The application of phosphate solubilizing microbes biofertilizer to increase soil P and yield of maize on ultisols Jatinangor. *KnE Life Sciences*, *2*(6), 179. https://doi.org/10.18502/kls.v2i6.1037

Getaneh, S., & Kidanemariam, W. (2021). Soil acidity and its managements: A review. *International Journal of Advanced Research in Biological Sciences*, *8*(3), 70–79. https://doi.org/http://dx.doi.org/10.22192/ijarbs.2021.08.03.008

Hanafi, D. F., Anwar, S., Santosa, D. A., Nugroho, B., & Baskoro, D. P. T. (2020). Transformation of aluminium fractions and phosphorus availability in acid soils as the result of microbes and ameliorant addition D. *J. Degrade. Min. Land Manage*, *7*(4), 2355–2362. https://doi.org/https://doi.org/10.15243/jdmlm.2020.074.2355

Islam, M. R., Sultana, T., Haque, M. A., Hossain, M. I., Sabrin, N., & Islam, R. (2018). Growth and yield of chili influenced by nitrogen and phosphorus. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, *11*(5), 54–68. https://doi.org/10.9790/2380-1105025468

Janati, W., Bouabid, R., Mikou, K., Ghadraoui, L. El, & Errachidi, F. (2023). Phosphate solubilizing bacteria from soils with varying environmental conditions: occurrence and function. *PLoS ONE*, *18*(12 December), 1–26. https://doi.org/10.1371/journal.pone.0289127

Khan, S., Irshad, S., Mehmood, K., Hasnain, Z., Nawaz, M., Rais, A., Gul, S., Wahid, M. A., Hashem, A., Fathi, E., & Ibrar, D. (2024). Biochar production and characteristics, its impacts on soil health, crop production, and yield enhancement: A review. *Plants*, *13*(166), 1–18. https://doi.org/https://doi.org/10.3390/plants13020166

Melini, F., Melini, V., Luziatelli, F., Abou Jaoudé, R., Ficca, A. G., & Ruzzi, M. (2023). Effect of microbial plant biostimulants on fruit and vegetable quality: current research lines and future perspectives. *Frontiers in Plant Science*, *14*(1251544), 1–20. https://doi.org/10.3389/fpls.2023.1251544

Muslim, R. Q., Kricella, P., Pratamaningsih, M. M., Purwanto, S., Suryani, E., & Ritung, S. (2020). Characteristics of Inceptisols derived from basaltic andesite from several locations in volcanic landform. *Sains Tanah*, *17*(2), 115–121. https://doi.org/10.20961/STJSSA.V17I2.38221

Nadeem, M., Wu, J., Ghaffari, H., Kedir, A. J., Saleem, S., Mollier, A., Singh, J., & Cheema, M. (2022). Understanding the adaptive mechanisms of plants to enhance phosphorus use efficiency on podzolic soils in Boreal agroecosystems.

Frontiers in Plant Science, *13*(804058), 1–23. https://doi.org/10.3389/fpls.2022.804058

Peringkat Sub Bagian (Huruf Besar Kecil, Cetak Miring, Rata Tepi Kiri) 3. (n.d.). *3*.

Prastia, B. (2017). Pengaruh pupuk NPK dan pemberian pupuk melalui daun terhadap pertumbuhan dan hasil tanaman cabai merah (Capsicum annum L). *BASELANG Jurnal Ilmu Pertanian, Peternakan, Perikanan Dan Lingkungan*, *02*(1), 30–37. https://doi.org/https://doi.org/10.36355/bsl.v2i1.36

Putriani, S. S., Yusnaini, S., Septiana, L. M., & Dermiyati. (2022). Aplikasi biochar dan pupuk P terhadap ketersediaan dan serapan P pada tanaman jagung manis (Zea mays Saccharata Sturt) di tanah ulitsol. *Jurnal Agrotek Tropika*, *10*(4), 615–626. https://doi.org/10.23960/jat.v10i4.6447

Rajaseger, G., Chan, K. L., Tan, K. Y., Ramasamy, S., Khin, M. C., Amaladoss, A., & Haribhai, P. K. (2023). Hydroponics: current trends in sustainable crop production. *Bioinformation*, *19*(9), 925–938. https://doi.org/10.6026/97320630019925

Rofidah, N. I., Yulianah, I., & Respatijarti. (2018). Korelasi antara komponen hasil dengan hasil pada populasi F6 tanaman cabai merah besar (Capsicum annuum L.). *Jurnal Produksi Tanaman*, *6*(2), 230–235.

Situmorang, Y., Nurbaity, A., & Simarmata, T. (2019). Efek komposisi dan dosis amelioran terhadap sifat tanah dan hasil tanaman cabai (Capsicum annuum L.) pada inceptisols. *Jurnal Agrotek Indonesia*, *4*(1), 26–29. https://doi.org/https://doi.org/10.33661/jai.v4i1.1280

Sonia, A. V., & Setiawati, T. C. (2022). Aktivitas bakteri pelarut fosfat terhadap peningkatan ketersediaan fosfat pada tanah masam. *Agrovigor: Jurnal Agroekoteknologi*, *15*(1), 44–53. https://doi.org/10.21107/agrovigor.v15i1.13449

Vondráčková, S., Hejcman, M., Tlustoš, P., & Száková, J. (2013). Effect of quick lime and dolomite application on mobility of elements (Cd, Zn, Pb, As, Fe, and Mn) in contaminated soils. *Polish Journal of Environmental Studies*, *22*(2), 577–589. https://doi.org/10.30638/eemj.2017.299

Yan, J., Bogie, N. A., & Ghezzehei, T. A. (2020). Root uptake under mismatched distributions of water and nutrients in the root zone. *Biogeosciences*, *17*(24), 6377–6392. https://doi.org/10.5194/bg-17-6377-2020

Youssef, M. A. (2016). Impact of biofertilizers on growth and yield of Moringa Oleifera Lam plants. *Al-Azhar Journal of Agricultural Research*, *26*(March 2016), 127–138.