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# Influence of phosphate and boron addition to mixed liquid fertilizer on the growth and yield of red chili cultivated in the subsoil layer

**Abstract.** This study assesses the impact of adding phosphate and boron in a mixed liquid fertilizer (MLF) on the growth and yield of red chili plants cultivated in a subsoil environment. The experiment was conducted to comprehend how these nutrients affect the performance of red chili plants, particularly when cultivated in less ideal conditions such as subsoil, a remnant of excavation for brick production. The research was carried out at the Ciparanje Garden of the Faculty of Agriculture, Universitas Padjadjaran. The research design employed a Randomized Completely Block Design with the following treatments: A = Control (degraded soil without fertilizer), B = 0% MLF + 1 NPK, C = 0.25% MLF + 1 NPK, D = 0.50% MLF + 1 NPK, E = 0.75% MLF + 1 NPK, F = 1.00% MLF + 1 NPK, G = 0.5% MLF + 3/4 NPK, H = 0.5% MLF + 1/2 NPK, I = 0.5% MLF + 1/4 NPK, J = 0.5% MLF + 0 NPK, and K = 1 NPK in normal soil. The results revealed that the addition of phosphate and boron in MLF significantly influenced the growth and yield of red chili in subsoil conditions. The recommended MLF concentration was 0.75%, alongside the standard NPK dose. These findings provide crucial insights for the development of more efficient and sustainable agricultural practices, especially in challenging soil conditions like subsoil, where nutrient availability can be a determining factor for agricultural success.

**Keywords**: Boron · Mixed Liquid Fertilizer (MLF) · Phosphor · Subsoil · Yield of red chili

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## Introduction

The growth of red chili (Capsicum annum) plays an important role in the world's food demand. However, various factors, such as soil conditions, could greatly affect plant growth and yield (Ibrahim et al., 2019; Qin et al., 2019). Less fertile soil layers, such as subsoil in red brick mining areas are less suitable for chili pepper production. Subsoil layers have different physical and chemical properties compared to the top soil layers, which can potentially affect nutrient availability for plant growth and development (Mesfin et al., 2018; Ning et al., 2022).

The availability of soil nutrients, such as phosphorus (P) and boron (B) is very important for the growth and development of chili plants. P plays a role in root development (Khanal et al., 2021) flowering, and fruiting (Karak et al., 2019). While B is important in the reproduction process of chili plants including the formation of flowers and fruit (Khanal et al., 2021; Faiziya et al., 2022; Thakur et al., 2023). The increasing of those nutrients availability is a prerequisite for supporting chili production, particularly in the less fertile subsoil area.

In situations where agricultural land is less fertile, mixed liquid fertilizers (MLF) offers a quicker response, making it a promising alternative (Phibunwatthanawong and Riddech, 2019). MLF have become a common choice for improving crop productivity because its main advantages are its ease of use and significant benefits for plants (Sadriddinovich et al., 2022). Additionally, MLF is water soluble, making it easy to apply. This solubility ensures that the nutrients in liquid fertilizer are available to meet the plant absorption needs. According to Ouyang et al., (2023), plants can absorb these nutrients through various parts, including roots, stems, and leaves (depending on application methods).

However, a specific research report about MLF on chili production in the subsoil layer is still limited. Therefore, further research is needed to understand the impact of adding P and B in MLF, as well as the effect on the growth and yield of red chili planted in the subsoil layer. This study is expected to solve the nutrient-lack challenges in degraded soil for supporting chili production.

## Material and Method

The research was conducted at the Experimental Field of the Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, Sumedang Regency, West Java, Indonesia, located at an elevation of approximately 768 meters above sea level. The soil used as the medium was subsoil retrieved from a red brick production area (soil layer at a depth of 50-10 cm). The red chili seeds were obtained from the Faculty of Agriculture's CB1 Varietal Breeding Program. The research activities encompassed various stages, commencing with the formulation of the MLF in the laboratory, simultaneous seed germination and the preparation of subsoil in polybags, the placement of the growing medium, transplanting inside a screen house, followed by maintenance, fertilization, and observations until harvesting.

This research employed a Randomized Completely Block Design (RCBD), consisting of combinations of MLF concentrations with NPK (urea, TSP, and KCl). The total number of treatment combinations was 10, with descriptions as follows: A = Control (degraded soil without fertilizer), B = 0% MLF + 1 NPK (150-80-100 kg/ha), C = 0.25% MLF + 1 NPK, D = 0.50% MLF + 1 NPK, E = 0.75% MLF + 1 NPK, F = 1.00% MLF + 1 NPK, G = 0.5% MLF + 3/4 NPK, H = 0.5% MLF + 1/2 NPK, I = 0.5% MLF + 1/4 NPK, J = 0.5 MLF + 0 NPK, and K = 1 NPK in normal soil. Each treatment was replicated three times, resulting in a total of 10 x 3 experimental units, amounting to 30 experimental units. Each experimental unit consisted of two individual plants, one for observation until harvest, and the other as a destructive sample for plant tissue analysis at the vegetative stage's maximum.

***Mixed Fertilizer Formulation.*** The fertilizer formula consisted of a mixture of solid and liquid cattle manure waste, molasses, and mineral nutrient sources, specifically phosphorus from rock phosphate and boron from boric acid. All components were weighed and mixed using water as a solvent, followed by a three-week (21 days) fermentation period. Upon the completion of fermentation, marked by the disappearance of foul odors, the mixed fertilizer was filtered and transferred to sealed bottles.

***Fertilizer Application.*** MLF for application was diluted in 1 liter of water, with varying concentrations according to each treatment. One percent (1%) of MLF was obtained by pipetting 10 ml of MLF into 990 ml of ion-free water. The application method involved spraying the diluted solution onto the entire plant.

The observation of plant height and stem diameter was conducted manually every week using a ruler and caliper. Plant tissue analysis (phosphorus and boron uptake) was carried out in the 6th week (42 days after planting). The plants were analyzed using $HNO_3$ and $HClO_4$ extractors, and the phosphorus and boron content was determined using a spectrophotometer. The data obtained from the instrument was multiplied by the plant's dry weight to obtain uptake data in percentage mass. Plant samples observed until harvest were intended to calculate yield components, which included fruit weight, fruit diameter, fruit length, and total number of fruits per plant.

***Data Analysis.*** Data analysis was performed using the SPSS Statistics 25.0 software. Data obtained from this structured experiment were input into the software to identify significant differences among the different treatment groups.

## Result and Discussion

***Plant Height.*** The addition of P and B to MLF significantly influences the height of red chili plants grown in the subsoil, affecting the growth and development of red chili plants. The height of red chili plants exhibited significant variation from the beginning to the end of the observation period. Differences in plant height among those subjected to MLF concentrations with NPK treatments showed growth patterns nearly identical to those in the normal soil treatment. An intriguing finding is that plants cultivated in the control treatment (subsoil) displayed suboptimal growth, while treatment J (subsoil with mixed liquid fertilizer) exhibited better growth, even in the absence of NPK fertilizer addition. The data for plant height growth, observed at weeks 2, 4, 6, and 8, are presented in Figure 1.

Thus, this research unveils that the addition of phosphate and boron in mixed liquid fertilizer, especially in combination with subsoil, has the potential to enhance the growth of red chili plants. Treatments C (0.25% MLF + 1 NPK), D (0.50% MLF + 1 NPK), F (1.00% MLF + 1 NPK), I (0.5% MLF + 1/4 NPK), and H (0.5% MLF + 1/2 NPK), I yielded significant and promising plant growth, and the results of this study provide valuable insights for the development of more efficient and sustainable agricultural practices.

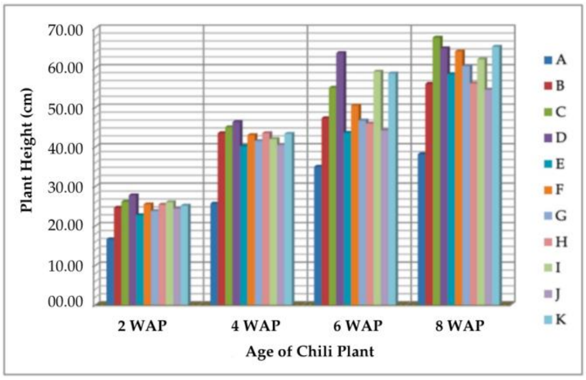


**Figure 1.** Height of red chili plants in various treatments.

Note: The description of treatments, as follows: A = Control (degraded soil without fertilizer), B = 0% MLF + 1 NPK (150-80-100 kg/ha), C = 0.25% MLF + 1 NPK, D = 0.50% MLF + 1 NPK, E = 0.75% MLF + 1 NPK, F = 1.00% MLF + 1 NPK, G = 0.5% MLF + 3/4 NPK, H = 0.5% MLF + 1/2 NPK, I = 0.5% MLF + 1/4 NPK, J = 0.5 MLF + 0 NPK, and K = 1 NPK in normal soil.

This finding aligns with the results of Zuniga et al. (2022), which concluded that a lack of phosphorus (P) can hinder the growth of chili plants, especially vegetative growth like plant height. Therefore, the addition of P can boost plant height growth in chili plants. Additionally, Wimmer et al. (2019) posited that boron is also crucial for plant growth, particularly in its role in cell wall formation and plant metabolism. A deficiency of B can disrupt plant growth, including height growth.

***Stem Diameter.*** The application of MLF with NPK also has a positive impact on the growth of the stem diameter in chili plants. Figure 2 illustrates significant differences in fertilizer application in subsoil. The stem diameter in the control treatment showed limited development, making it the smallest. Several MLF treatments with NPK enhanced the stem diameter of chili plants in subsoil media, matching that of the normal soil treatment, with some even surpassing it.

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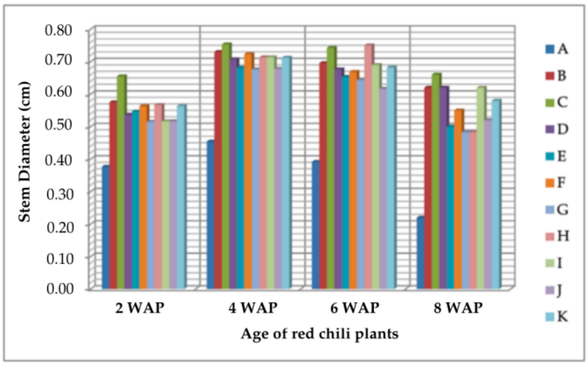



**Figure 2. Stem diameter of red chili plants in various treatments.**
Note: The description of treatments, as follows: A = Control (degraded soil without fertilizer), B = 0% MLF + 1 NPK (150-80-100 kg/ha), C = 0.25% MLF + 1 NPK, D = 0.50% MLF + 1 NPK, E = 0.75% MLF + 1 NPK, F = 1.00% MLF + 1 NPK, G = 0.5% MLF + 3/4 NPK, H = 0.5% MLF + 1/2 NPK, I = 0.5% MLF + 1/4 NPK, J = 0.5 MLF + 0 NPK, and K = 1 NPK in normal soil.

Based on the research by Jayapala *et al*. (2019), the addition of phosphorus (P) improved the stem diameter of chili plants by increasing cell wall thickness and tissue quality. Furthermore, as indicated by Omotade (2019), cell wall enlargement is also influenced by boron uptake, where the proper addition of boron can help ensure optimal cell wall formation, facilitating the development of stem diameter.

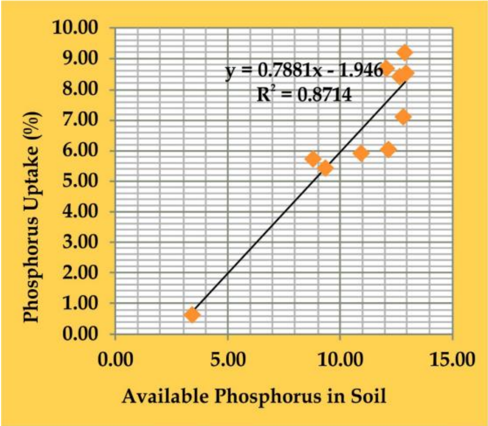
***Phosphorus and Boron Uptake.*** The application of MLF with NPK on red chili plants optimizes the absorption of P and B as indicated by the uptake value. Table 9 below presents the result of the analysis of P and B tissue uptake of chili plants. Treatments with 0.50%, 0.75%, and 1.00% MLF with a single NPK dose showed the highest P and B uptake. On the other hand, chili plants planted in the control treatment (without fertilizer) showed significant nutrient uptake. According to Mitran et al. (2019), P from fertilizers helps in the formation and growth of strong roots, increasing the ability of plants to absorb available P.

Boron in the MLF formula functions as an easily absorbable for plants, facilitating the transport of B from the root to the upper parts of the plant. This observation is also supported by Sopha and Murtiningsing (2020), who stated that the utilization of B in the form of liquid fertilizer has a significant impact on the more efficient use of B by plants for the formation of high quality chili flowers and fruits.

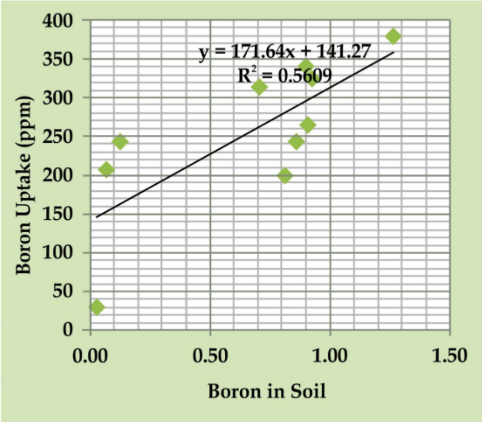
**Table 1. Phosphorus (P) and Boron (B) uptake by chili plants at 6 Weeks After Transplanting (WAT)**

| Treatments | | Phosphor Uptake (%) | | Boron Uptake (ppm) | |
|---|---|---|---|---|---|
| A | Control | 0.64 | a | 80.28 | a |
| B | 0 % MLF +1 NPK | 1.42 | bc | 96.48 | ab |
| C | 0.25 % MLF + 1 NPK | 1.90 | bc | 203.45 | bc |
| D | 0.50 % MLF + 1 NPK | 2.49 | c | 312.59 | c |
| E | 0.75 % MLF + 1 NPK | 2.51 | cd | 324.06 | cd |
| F | 1.00 % MLF + 1 NPK | 2.62 | c | 378.51 | d |
| G | 0.50 % MLF + 3/4 NPK | 2.54 | cd | 239.26 | bc |
| H | 0.5% MLF + 1/2 NPK | 1.12 | b | 234.55 | bc |
| I | 0.50 MLF + 1/4 NPK | 1.08 | b | 226.24 | bc |
| J | 0.50 MLF + 0 NPK | 0.81 | ab | 221.12 | bc |
| K | 1 NPK Normal Soil | 2.65 | d | 382.94 | e |

Description: P and B uptake are presented per dry weight of red chili plant. The average value of treatments in the same column followed by the same letter did not differ based on Duncan's Multiple Range Test (DMRT) The mean value of the treatment in the same column followed by the same letter was not at a significance level of 5%.
The description of treatments, as follows: A = Control (degraded soil without fertilizer), B = 0% MLF + 1 NPK (150-80-100 kg/ha), C = 0.25% MLF + 1 NPK, D = 0.50% MLF + 1 NPK, E = 0.75% MLF + 1 NPK, F = 1.00% MLF + 1 NPK, G = 0.5% MLF + 3/4 NPK, H = 0.5% MLF + 1/2 NPK, I = 0.5% MLF + 1/4 NPK, J = 0.5 MLF + 0 NPK, and K = 1 NPK in normal soil.




(a)




(b)

**Figure 3. (a) Correlation between available P in soil with P uptake (b) Correlation between available B in soil with B uptake**

The availability of P in the soil has a positive correlation with P uptake by chili plant, as shown by Pereira et al. (2020). This correlation was identified because P is an essential nutrient that supports various aspects of plant growth and development as highlighted by Bhatana et al. (2021). P is required for the formation of ATP molecules, which carry energy within plant cells, activate key enzymes for metabolism, facilitate the growth of strong roots for nutrient and water absorption, and are important in fruit and seed development.

If the P is at sufficient level in the soil, chili plants can optimize their growth (Putra et al., 2020), produce high-quality fruits (Islam et al., 2018), and obtain better yields (Elhaissoufi et al., 2019).

Figure 3(a) shows an $R^2$ of 0.87, indicating that approximately 87% of the variation in P uptake by chili can be explained by the variation in soil P availability within the regression model. This suggests a strong relationship between these two variables in the linear regression model, with most of the variance in P uptake by chili plants being attributed to variations in soil P availability used in the analysis. The availability of boron in the soil has an approximately 56% impact ($R^2$ of 0.56) on the amount of boron absorbed by chili plants (Figure 3b). This implies that not all of the variation can be explained solely by soil boron availability, with approximately 44% being influenced by other factors affecting boron uptake by chili plants.

**Table 2. Red chili yield components in various treatments.**

| Treatment | Fruit weight (g) | Fruit length (cm) | Fruit Diameter (cm) | Fruit weight /plant (g) |
|---|---|---|---|---|
| A = Kontrol | 5.00 a | 9.50 a | 0.87 a | 559 a |
| B = 0 % Mix Liquid Fertilizer + 1 NPK | 6.87 b | 12.8 bc | 1.06 bc | 1040 c |
| C = 0.25 % Mix Liquid Fertilizer + 1 NPK | 7.05 bc | 13.15 bc | 1.18 c | 1231 d |
| D = 0.50 % Mix Liquid Fertilizer + 1 NPK | 6. b | 13.45 c | 1.19 c | 1263 de |
| **E = 0.75 % Mix Liquid Fertilizer + 1 NPK** | **7.03 bc** | **13.43 c** | **1.20 cd** | **1285 e** |
| **F = 1.00 % Mix Liquid Fertilizer + 1 NPK** | **7.11 b** | **13.25 bc** | **1.21 cd** | **1283 e** |
| G = 0.5 % Mix Liquid Fertilizer + 3/4 NPK | 7.07 bc | 12.55 b | 1.19 c | 1173 cd |
| H = 0.5% Mix Liquid Fertilizer + 1/2 NPK | 6.55 ab | 10.56 ab | 1.07 bc | 1006 bc |
| I = 0.5 Mix Liquid Fertilizer + 1/4 NPK | 6.48 ab | 10.23 ab | 1.01 b | 994 bc |
| J = 0.5 Mix Liquid Fertilizer + 0 NPK | 5.13 a | 9.61 a | 0.95 ab | 898 b |
| **K = 1 NPK Normal Soil** | **7.24 c** | **13.47 c** | **1.28 d** | **1301 e** |

**Description:** The mean value of the treatment in the same column followed by the same letter was not different based on DMRT at the 5% significance level

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***Yield.*** Several essential variables for assessing the impact of fertilizer application on red chili commodities include fruit weight, fruit diameter, fruit length, and the total number of fruits per plant (Kusumiyati et al., 2022). The data presented in Table 2 indicate that the application of MLF containing phosphorus and boron, along with NPK, significantly affects the quality and quantity of red chili fruits. Fruit weight, which was not significantly different from treatment K (normal soil), was observed in treatments C (0.25 % MLF + 1 NPK), E (0.75 % MLF + 1 NPK), and G (0.5 % MLF + 3/4 NPK).

Additionally, for the fruit length parameter, treatment D (0.50% MLF + 1 NPK) was among the best treatments, as their results were comparable to the normal soil treatment and demonstrated similar fruit weight and diameter characteristics. Furthermore, treatments E (0.75 % MLF + 1 NPK and F (1.00 % MLF + 1 NPK) showed fruit diameter sizes equivalent to those in the normal soil treatment. These findings indicate that the application of MLF alongside NPK Fertilizer significantly influences the quality of red chili fruit, confirmed by the increased fruit weight, length, and diameter compared to the control and standard fertilizer treatment. The uptake of nutrients N, P, and K by plants is influenced by their nutrient availability. Nutrient uptake by chili plants continues as long as the plant requires these nutrients for growth and development (Dubey et al., 2016).

Based on findings of Wirajaya et al., (2022), P fertilization has a significant impact on increasing yield components, such as the size, length, and weight of chili fruits. Furthermore, Malik et al. (2020) and (Kamalakannan et al., 2020) stated that the availability of B can increase the weight and thickness of chili fruits.

## Conclusion

This research showed that the application of MLF containing P and B could influence plant growth parameters, such as plant height and stem diameter. The availability of P and B in the soil is positively correlated with their uptake by plants, even though a significant portion of B is absorbed through the leaves due to insufficient boron availability in the subsoil medium. Meanwhile, the correlation between P soil and the P uptake remained high due to the addition of NPK fertilizer to the media. In addition, several yield components such as fruit weight, fruit length, and fruit diameter were also improved as the effect of MLF application compared to the control and basic fertilizer application.

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