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Analysis of Potassium (K) Uptake and Plant Growth of Lettuce (*Lactuca sativa* L.): Effect of AB Mix Concentrations and NPK Fertilizer Doses

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ABSTRACT

Soil is a crucial growing medium that supplies nutrients essential for plant development. This study aimed to evaluate the effect of AB Mix concentrations and NPK fertilizer dosages on potassium (K) uptake, growth, and yield of lettuce (Lactuca sativa L.). The experiment was conducted from June to September 2024 in Nupabomba Village, Donggala Regency, and in the Soil Science Laboratory of Tadulako University, using a factorial Randomized Complete Block Design (RCBD). The first factor was AB Mix concentration: A0 (control), A1 (24 ml/3 L), and A2 (1,800 ppm = 27 ml/3 L). The second factor was NPK dosage: D0 (control), D1 (0.7 g/7 kg), and D2 (1.4 g/7 kg). Data were analyzed using ANOVA followed by the Honest Significant Difference (HSD) test at a 5% significance level. Results showed that AB Mix and NPK fertilizer significantly affected potassium content in plant tissue but did not significantly affect soil pH, C-organic content, soil potassium levels, or potassium uptake. Treatments significantly increased plant height, number of leaves, and fresh weight, while dry weight was unaffected. These findings indicate that appropriate AB Mix and NPK combinations enhance lettuce growth and yield by improving tissue potassium content without altering soil properties.

1. INTRODUCTION

Lettuce (*Lactuca sativa* L.) is one of the horticultural crops that is widely cultivated because it has high commercial value and stable market demand throughout the year (Helay *et al*., 2021; Chatzistathis *et al*., 2024). As a leaf plant that is consumed fresh, lettuce requires an optimal supply of nutrients to support vegetative growth and produce quality results. Among the essential nutrients, potassium (K) has a vital role in plant physiological processes, including enzyme activation, transport of photosynthesis products, and regulation of osmotic pressure (Wardhana *et al*., 2024). Suboptimal potassium uptake can cause metabolic disorders, not optimal growth, and a decrease in the quality and quantity of crop yields (Jama-Rodzenska *et al*., 2022; Abdel-Hakim *et al*., 2023; Kavvadias *et al*., 2023).

Correct fertilization practices are one of the keys to supporting the availability of nutrients for plants. Currently, the two types of fertilizer that are widely used are AB Mix and NPK fertilizer (Hindersah *et al*., 2023; Harsela, 2024). AB Mix is a completely formulated fertilizer and is usually used in hydroponic systems, because its nutrient content is easily soluble and available directly to plants. On the other hand, NPK fertilizer is more widely used in conventional planting systems because it is more economical and easy to apply (Khodijah & Kusmiadi, 2021). Each of these fertilizers has its own advantages, but there is not much information comparing the effectiveness of the two in increasing potassium uptake and lettuce crop yields simultaneously (Nurhayati *et al*., 2024; Aina *et al*., 2025).

Several previous studies have examined the effect of AB Mix fertilizer and NPK fertilizer separately on plant growth. Research by Mostafa *et al*. (2019) showed that increasing the AB Mix concentration to a certain limit can accelerate

growth and increase the wet weight of hydroponic kale plants. Meanwhile, Muscolo *et al*. (2022) found that NPK fertilizer application increased the number of leaves and height of spinach plants. Although the results of this research provide a general picture, there has been no study that specifically highlights the comparison of these two types of fertilizer on the parameters of potassium uptake, growth and yield of lettuce plants.

Research that compares the effect of various AB Mix and NPK fertilizer concentrations directly on one type of plant will provide more complete information regarding the effectiveness and efficiency of fertilizer use. This is important considering that the need for cultivation methods that are cost-effective but still produce high productivity continues to increase, especially among small-scale farmers and urban farmers. Therefore, a deeper understanding of the relationship between the type and concentration of fertilizer with nutrient uptake and crop yield will be very useful for decision making in sustainable cultivation. This research aims to determine the nutrient uptake of potassium (K), growth and yield of lettuce (*Lactuca sativa* L.) when given various concentrations of AB Mix fertilizer and NPK fertilizer. It is hoped that the results of this research can become a scientific and practical reference in determining the right dose and concentration of fertilizer to increase fertilization efficiency and lettuce production.

2. MATERIALS AND RESEARCH METHODS

This research was carried out from June to September 2024in Nupabomba Village, Tanamantovea District, Donggala Regency, Central Sulawesi, in the Tanahi Science Laboratory, Tadulako University, Palu, and in the UPTD Laboratory for Goods Quality Testing & Certification, Palu City. The tools used are hoes, measuring tape, shovels, knives, cameras, buckets, polybags (size 30 cm mix 40 cm), writing tools and laboratory equipment. The ingredients used are lettuce, AB mix nutrition, NPK fertilizer, husk charcoal, soil, laboratory labels.

This research was structured using a factorial Randomized Group Design (RAK). The first factor is the AB mix concentration (A) and the second factor is the NPK fertilizer dose (D). There were three AB mix concentrations tested, namely A0 (Control), A1 (24 mL/3 L), and A2 (27 mL/3 L). The AB Mix concentration and NPK fertilizer dosage were determined based on literature and recommendations for fertilizing leafy vegetables. The AB Mix concentrations consisted of A0 (control), A1 (24 ml/3 L ≈ 1,600 ppm), and A2 (27 ml/3 L = 1,800 ppm). This concentration is in the optimum range for lettuce plants to increase plant height, number of leaves, and fresh weight without causing phytotoxicity (Rosnina & Mauliza, 2020; Rahmawati *et al*., 2022). There were three NPK fertilizer dosages tested, namely D0 (Control), D1 (0.7 g/7 kg ≈ 200 kg/ha), and D2 (1.4 g/7 kg ≈ 400 kg/ha). A dose of 200 kg/ha was chosen because it is the general recommendation for NPK fertilization on lettuce, while D2 is a double dose to test the response to a higher dose. The conversion of kg/ha dose to grams per pot is calculated based on the assumption of a topsoil depth of 20 cm and a bulk density of 1.0 g/cm³, so that the equivalent soil mass per hectare is 2,000,000 kg. Thus, 200 kg/ha is converted into 0.7 g for 7 kg of soil per polybag. This approach is commonly used in pot fertilization research to evaluate plant response in a controlled manner. Table 1 summarized the treatment combinations of the two factors.

Table 1. Treatment combination of AB Mixed concentration and NPK fertilizer

Treatment	D_0 (Control)	D_1 (0.7 g/7 kg)	D_2 (1.4 g/7 kg)
A_O	A_0 D_0	A_0D_1	A_0D_2
(Control)	(Control + Control)	(Control + 0.7 g/7 kg)	(Control + 1.4g/7 kg)
A_1	A_1D_0	A_1D_1	A_1D_2
(24 ml /3 liter)	(24 ml /3 liter + Control)	(24 ml /3 liter + 0.7g/7 kg)	(24 ml /3 liter + 1.4 g/7 kg)
A_2	A_2D_0	A_2D_1	A_2D_2
(27 ml /3 liter)	(27 ml /3 liter + Control)	(27 ml /3 liter + 0.7 g/7 kg)	(27 ml /3 liter + 1.4 g/7 kg)

2.1. Preparation of Planting Media and Preparation of Nutrients

The planting medium used is a mixture of soil and husks. Soil is taken from farmers' gardens by hoeing the top layer of soil to a depth of 20 cm, then cleaned of plant roots and weeds. The clean soil amounting to 7 kg/polybag was put into polybags of 30 × 40 cm size. Lettuce seeds were sown first in prepared polybags, generally the seeds grow or begin to germinate after 3 to 4 days after sowing. Keep watering the seeds regularly. The seedlings were transplanted into the prepared polybags after they were 7 days old.

At the beginning of transplanting, each polybag was watered with ±250 mL/day until the lettuce seedlings grow well and aDATt to the planting medium. Once the plants look fresh and start to grow normally, water them 2-3 times per week sufficiently to maintain the humidity of the media. The amount of water given was made the same for all treatments so that the research results were only influenced by the addition of AB Mix and the dose of NPK fertilizer. Weeding was done manually by pulling out weeds growing in the planting medium every time weeds start to appear.

2.2. Treatment Application

Application was carried out by providing AB Mix nutrition and NPK fertilizer according to the concentration tried on each plant. This application was carried out when the plants were two weeks after planting (WAP) and was given three times at the plant age of 14, 28, and 42 day after transplanting (DAT).

2.3. Harvest

Lettuce plants were harvested between 30 and 70 days after planting. Harvesting lettuce was done by removing all parts of the vegetable along with the roots or by cutting the base of the stem of the plant on the ground (Figure 1).

Figure 1. Lettuce plant ready for harvesting (left) and just after harvesting (right)

2.4. Soil Analysis Before and After Application of AB Mix and NPK Fertilizer

The soil samples taken were then taken to the Soil Science Laboratory for analysis of their chemical properties. Soil samples were taken twice, namely before treatment to determine the initial condition of the soil and after harvesting lettuce to see changes in chemical properties due to AB Mix and NPK fertilizer treatment. The procedure for analyzing soil chemical properties is that first the soil sample is composited, then air-dried for three days. After that, the soil was smoothed by pounding and sifting using a 2 mm and 0.5 mm sieve before laboratory analysis was carried out.

3. RESULTS AND DISCUSSION

3.1. Soil Analysis

From the results of the soil analysis, soil samples were taken before addition the AB Mix concentration and NPK fertilizer, the results of the pH, C-organic and potassium (K) analysis were presented in Table 2. It shows that the soil taken for this research has a pH H_2O value of 5.59 with slightly acidic criteria. Furthermore, the organic C contained in the soil is 1.79 with low criteria. Meanwhile, the K content in the soil is very low, namely 0.37 with low criteria.

The initial soil analysis sample obtained a high soil pH, this was because the research area was an area with high rainfall, so the soil became acidic. Mohammed *et al*. (2022) stated that in several tropical regions, the problem of soil acidification often occurs due to raw materials or intensive agricultural practices. One type of soil that is affected by quite high acidity in this region is inceptisol and ultisol soil. High rainfall increases nutrient leaching, acid weathering of parent material, and intensive agricultural activities, leading to increased soil degradation in the region (Rashwanat

& Elsaied, 2022). However, in the initial analysis, low C-organic values were obtained. This is caused by the depth of soil sampling being too deep so that the soil organic matter content becomes lower. Kavvadias *et al*. (2023) stated that the factor that can influence the value of C-organic is soil depth. The higher the C-organic value in the soil, the lower the C-organic value.

Table 2. Soil analysis before applying AB Mix concentration and NPK fertilizer

Variable	Value	Criteria
pH H_2O	5.59	Slightly acid
C-organic	1.79%	Low
K_2O HCl 25%	0.37%	Low

The potassium content in the soil in the initial analysis was found to be low because the soil sample used had an acid pH. Aina *et al*. (2025) stated that the causes of high and low potassium concentrations in the soil are influenced by raw materials and soil IPH. Acidic soil increases K fixation and thus reduces the availability of element K in the soil. Potassium deficient plants may experience spotting, yellowing, and necrosis, especially on the tips of the leaves.

3.2. Soil Analysis After Treatment

3.2.1. Soil pH

The results of variance analysis show that the application of AB mix and NPK fertilizer as well as their interaction did not have a real effect on soil pH. The significance value (*p*-value) was 0.8053 for AB mix, 0.4501 for NPK dose, and 0.9139 for the interaction. Based on the known results in Figure 2, it shows that the highest average soil pH was found in the A0D0 treatment with an average of 6.27. Meanwhile, the lowest average soil pH was found in the A0D2 treatment with an average of 5.27. The A0D0 (control) treatment resulted in a soil pH that remained high or the same as the initial condition without treatment, namely 6.27. This is because the soil before treatment was classified as acid soil. On the other hand, the lowest soil pH was found in the A0D2 treatment (AB Mix = control + NPK = 1.4 g/7 kg) namely 5.27, which was thought to be due to the use of a high dose of NPK which reduced the soil pH. This is in line with the results of soil analysis which show relatively high soil chemical content.

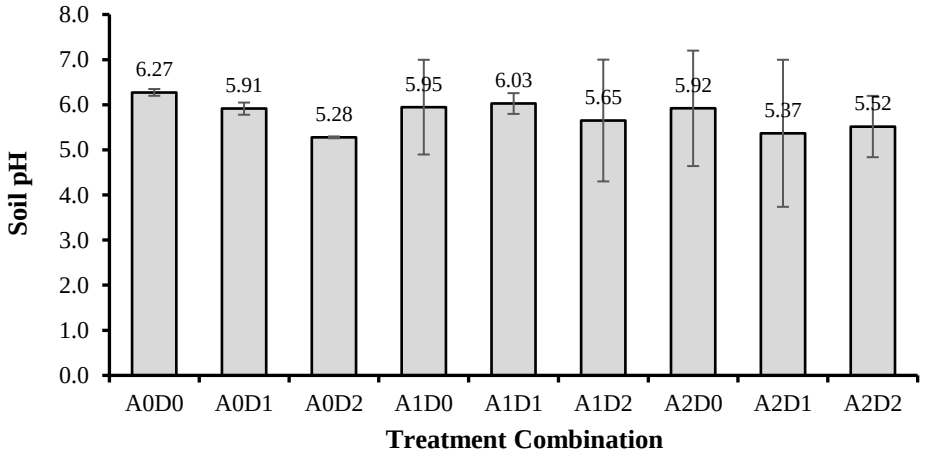

Figure 2. Effect of treatment combination (AB Mix and NPK fertilizer) on soil pH. [Error bars are standard deviation of three replications]

3.2.2. Soil C-Organic

The results of variance analysis show that the application of AB Mix and NPK fertilizer does not have a real effect on soil C-organic. The significance value (*p*-value) was 0.2230 for AB mix, 0.2778 for NPK dose, and 0.7364 for the

interaction. Based on the results known from Figure 3, it shows that the highest soil organic C value, namely 3.20%, is found in sample A0D1. Meanwhile, the lowest organic C value was 1.88% found in sample A2D0.

The increase in soil C-organic after addition AB mix and NPK fertilizer concentrations in the A0D1 treatment (AB mix = control + NPK = 0.7 gram/7 kg), this is because the dose used can cause an increase in soil C-organic from 1.88% to 3.21%. Khan *et al*. (2019) stated that the smaller the amount of NPK fertilizer given, the greater the effect it will have on increasing soil organic C. In addition, increasing soil organic content can help maintain soil fertility and protect soil and water quality related to nutrients, water and biological cycles, and furthermore soil improvement serves as an important indicator of the quality and sustainability of agricultural systems. So it can play an important role in influencing soil quality and productivity (Atero-Calvo *et al*., 2023).

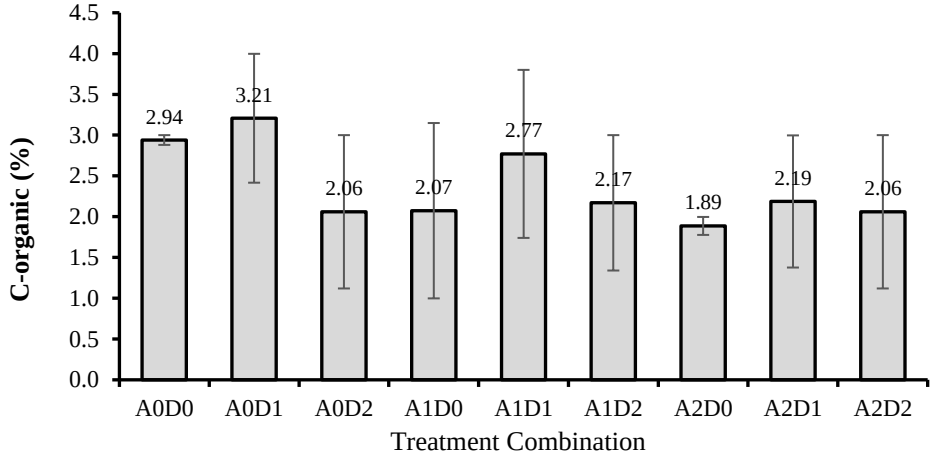

Figure 3. Effect of treatment combination (AB Mix and NPK fertilizer) on soil C-organic. [Error bars are standard deviation of three replications]

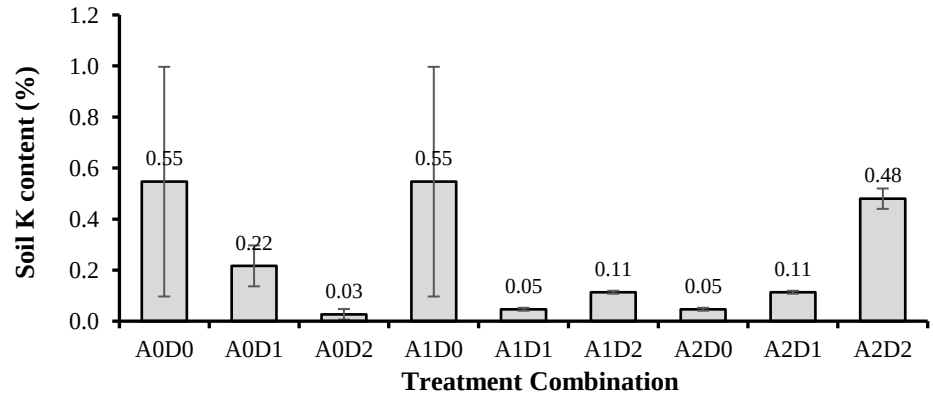

Figure 4. Effect of treatment combination (AB Mix and NPK fertilizer) on soil potassium (K) content. [Error bars are standard deviation of three replications]

3.2.3. Soil Potassium (K)

The results of the analysis of variance showed that the application of AB mix and NPK fertilizer did not have a significant effect on soil potassium content. This is reflected from the significance values (*p*-value), which was 0.8851 for AB mix, 0.0598 for NPK dose. The *p*-value of the interaction of the two factors is 0.0083, but still insignificant for soil K content due high variability of the replication data within the treatent. Based on the results known from Figure 4, it shows that the highest soil K is 0.55% in samples A0D0 and A1D0, while the lowest soil K value was 0.02% in sample A0D2.

Providing concentrations of AB mix and NPK fertilizer can cause an increase in soil potassium in treatments A0D0 (control) and A1D0 (AB mix = 24 ml/3 liters + NPK = control) from 0.37% to 0.54%, this is because the dose used can provide an increase in potassium in the soil compared to other treatments. Jama-Rodzenska *et al*. (2022) stated that the element potassium can regulate stomata and photosynthesis. Therefore, increasing the availability of potassium in the soil and motivating plants to dig deeper roots will increase the drought resistance of plants. Potassium is one of the main nutrients of the three nutrients Nitrogen (N) and Phosphorus (P) needed by plants and can affect the quality of plant production. In addition, the nutrient potassium is very important in all plant metabolic processes, as well as in the synthesis of ammonium ions, amino acids and proteins (Chatzisthathis *et al*., 2024).

3.2.4. Potassium (K) in Plant Tissue

The results of variance analysis show that the interaction of AB mix and NPK fertilizer has a very significant influence on K plant tissue with p-value of 0.000. Based on the results known from Figure 5, it shows that the highest K value for lettuce plant tissue, namely 4.54%, is found in sample A0D2. Meanwhile, the lowest K value for lettuce tissue was 0.03% in sample A2D2.

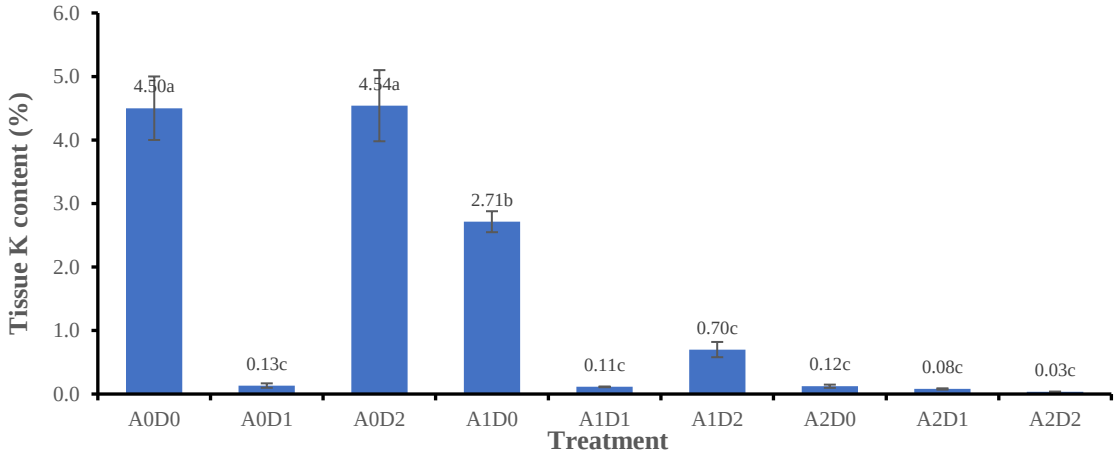

Figure 5. Effect of treatment combination (AB Mix and NPK fertilizer) on the potassium (K) content in plant tissue of lettuce

Providing an effective concentration of AB mix and NPK fertilizer through the 5% LSD test table on the K value of lettuce plant tissue was found in the AB mix (control) + NPK fertilizer (1.4g/7 kg) treatment marked with the highest notation, namely c. Meanwhile, the efficient concentration of AB mix and NPK fertilizer was found in the AB mix = (control) + NPK fertilizer dose (control) or without treatment.

Providing concentrations of AB mix and NPK fertilizer caused an increase in plant tissue K in the A0D2 treatment (AB mix = control and NPK = 1.4 g/7 kg) from soil K absorption of 0.02% to 4.5% in plant tissue K compared to other treatments. This is due to the high pH value and increase in K in the soil. Tahiri *et al*. (2022) stated that the potassium element absorbed by plants from the soil is involved in cell structure, assimilation, synthesis of proteins, amino acids and sugars, the entry of water into plants, the transfer of carbohydrate products processed in leaves to stems, and the enzymatic activity of photosynthetic plants used in plant tissue cells. Factors that influence the level of potassium absorbed by plants are the condition of potassium in the soil, pH, content and type of clay minerals, nutrient content of the soil layer, content of soil organic matter, type and variety of plants, root form, level of production, and climate. Increasing crop production can be done by means of balanced fertilization, namely applying fertilizer to the soil in quantities and types of nutrients that meet the plant's needs.

3.2.5. K-Uptake

The results of variance analysis showed that the interaction of AB mix and NPK fertilizer had a significant effect on K uptake with *p*-value 0.046. Based on the results known from Figure 6, it shows that the highest K uptake value was

found in the A0D2 treatment with an average of 7.65%. Meanwhile, the lowest K uptake value in lettuce plants was 0.07% in the A2D2 treatment.

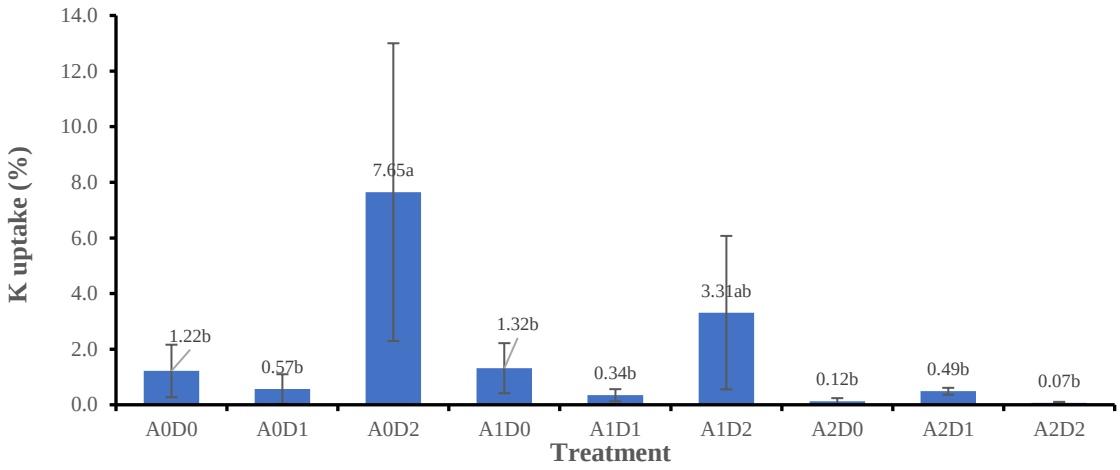

Figure 6. Effect of treatment combination (AB Mix and NPK fertilizer) on K-uptake by lettuce plants

The reason for the high K uptake in plants, after calculating the highest yield, was obtained in the A0D2 treatment (AB mix + control + NPK fertilizer = 1.4 g/7 kg), this was due to the absorption of potassium in the lettuce plant tissue and the high dry weight in the A0D2 treatment. Mancho et al. (2023) stated that the value of potassium uptake in plants can be influenced by the value of potassium content in plant tissue and the dry weight of the plant. To observe potassium levels in plant tissue, plant leaves are used as laboratory test material and carried out at 35 HST or when the plants are harvested. Plant potassium uptake in plant tissue can be influenced by the dry weight of the plant and also the potassium content in the plant. Therefore, as potassium levels and dry weight of plants increase, potassium absorption by plants will also increase. Potassium uptake by plants is also influenced by the availability of potassium in the soil or the nutrients provided to plants. The higher the potassium availability of a plant, the higher the potassium absorption by the plant. Increasing the uptake of potassium elements in plant leaves increases the availability of potassium elements in other plant organs.

3.2.6. Plant Height

Based on the results of various variable observations of lettuce plant height, it shows that the addition of AB mix and NPK fertilizer concentrations had a significantly different effect on the height of lettuce plants aged 28 and 42 DAT, the *p*-value of AB mix was 0.018 at age 28 DAT and 0.016 at age 42 DAT. Meanwhile the *p*-value of NPK factor was 0.000 at both ages.

Table 3. Average height (cm) of lettuce plants at 28 DAT

Treatment	D_0	D_1	D_2	Average
A_0	6.3	11.3	11.8	9.8 ^{b}
A_1	8.7	13.7	13.3	11.9 ^{ab}
A_2	8.7	15.3	13.0	12.3 ^{a}
Average	7.9 ^{B}	13.3 ^{A}	12.7 ^{A}	

Note: values followed by different letters are significantly different at the 5% LSD test. Lowercases for AB mix and uppercases for NPK dose.

Table 3 shows that lettuce plants at the age of 28 HST produced the highest average, namely 15.3 cm, in the A2D1 treatment. Meanwhile, the A0D0 treatment produced the lowest average, namely 6.3 strands. Table 4 shows that lettuce plants at the age of 42 HST had the highest average in the A2D1 treatment, namely 20.3 cm. Meanwhile, the A0D0 treatment produced the lowest average, namely 8.7 cm.

Table 4. Average height (cm) of lettuce plants 42 DAT

Treatment	D_0	D_1	D_2	Average
A_0	8.7	14.7	15.7	13.0 [b]
A_1	11.3	19.3	17.7	16.1 [a]
A_2	11.3	20.3	17.7	16.2 [a]
Average	10.4 [B]	18.1 [A]	16.8 [A]	

Note: values followed by different letters are significantly different at the 5% LSD test. Lowercases for AB mix and uppercases for NPK dose.

Providing an effective and efficient concentration of AB mix and NPK fertilizer using the 5% LSD test table on lettuce plant height was found in the AB mix (27 ml/3 liter) + NPK fertilizer (0.7 g/7 kg) treatment marked with the highest notation, namely bc. This is because this treatment is the right dose to support growth in lettuce plants. Harsela (2024) states that providing nutrient solutions with the right concentration can meet plant nutritional needs, support plant growth, and increase plant production. The growth of vegetable plants such as lettuce requires nutrients that can provide the macro nutrient NPK at a higher concentration than other nutrients. An increase in the height of lettuce plants over time can indicate that lettuce plants are undergoing cell division and expansion to encourage plant growth, and also providing timely fertilizer influences plant growth (Suryatmana *et al*., 2021).

3.2.7. Number of Leaves

Based on the results of ANOVA test, NPK fertilizer dose had significant effect on the number of leaves of lettuce at age 28 DAT with *p*-value = 0.003. AB mix factor and its interaction with NPK did not significantly influence number of leaves. At age 42 DAT, both factors significantly affect the number of leaves with *p*-value of 0.000 for all. The interaction of both factors, however, did not significantly influence the number of leaves of the lettuce (p-value = 0.169). Based on the results shown in Table 5, the concentration of AB mix and NPK fertilizer has a very significant and significantly different effect on the number of leaves on lettuce plants at 42 HST (Table 6). Treatment A2D1 got the highest average of 20.07 strands, and the lowest number of leaves was found in the A0D0 treatment with an average of 8.0 pieces.

Table 5. Average number of leaves on lettuce plants 28 DAT

Treatment	D_0	D_1	D_2	Average
A_0	6.7	9.7	9.0	8.47 [a]
A_1	6.7	10.0	11.3	9.33 [a]
A_2	7.0	13.7	10.0	10.23 [a]
Average	6.80 [B]	11.13 [A]	10.10 [A]	

Note: values followed by different letters are significantly different at the 5% LSD test. Lowercases for AB mix and uppercases for NPK dose.

Table 6. Average number of leaves on lettuce plants 42 DAT

Treatment	D_0	D_1	D_2	Average
A_0	8.0	14.0	12.7	11.6 [b]
A_1	9.3	20.7	15.3	15.1 [a]
A_2	10.7	20.7	18.7	16.7 [a]
Average	9.3 [C]	18.4 [A]	15.6 [B]	

Note: values followed by different letters are significantly different at the 5% LSD test. Lowercases for AB mix and uppercases for NPK dose.

Providing fertilizer with a low concentration will result in the availability of nutrients in the soil not being optimal and unable to meet the plant's nutrient needs (Gabriel *et al*. 2023). Providing effective and efficient AB mix concentration and NPK fertilizer dosage using the 5% LSD test table on the number of leaves of lettuce plants was found in the AB mix (27 ml/3 liter) + NPK fertilizer (0.7 g/7 kg) treatment marked with the highest notation, namely c. This is because the high dose of AB mix and the dose of NPK fertilizer used can increase the number of leaves on lettuce plants. Meanwhile, without treatment you cannot increase the number of lettuce plant leaves. According to Gustiar *et al*. (2025) stated that the higher the dose of AB mix that is given to lettuce plants, the more the number of leaves on the lettuce

plants will increase. The nutrients absorbed by plant roots deliver the nutrients to the leaves, where the photosynthesis process occurs and can break down the nutrients needed by the plant, so that the energy produced is likely to be used for the growth process, encouraging plant growth and the number of leaves. Increasing the dose of NPK fertilizer allows plants to absorb more nutrients and also grow.

4. CONCLUSION

Initial analysis showed soil H_2O pH 5.59, organic C 1.79%, and K content 0.37%. The application of AB Mix and the dose of NPK fertilizer had a significant effect on the K content of lettuce plant tissue, but had no significant effect on soil pH, organic C, soil K content, or K uptake. Plant height, number of leaves, and fresh weight showed a very significant and significantly different effect, while dry weight was not affected. Based on these results, the application of AB Mix 27 ml/3 L (1,800 ppm) and NPK fertilizer 200 kg/ha (0.7 g per pot) is recommended as the optimal rate to increase vegetative growth and yield of lettuce on soil with similar characteristics without changing the chemical properties of the soil. Future research is recommended to test the response of different lettuce varieties, explore a wider range of AB Mix concentrations to determine the optimum point, assess the effect on leaf nutritional quality, and evaluate the long-term impact of repeated applications on soil chemical and biological properties.

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