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Evaluation Composition Nutrients in Plants Lettuce (*Lactuca sativa*) Hydroponics With Various Formulation Fertilizer

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Abstract
Lettuce is a popular leafy vegetable among the community. The expansion and potential of lettuce cultivation require efficient growing techniques. The production of plants using a hydroponic system is closely linked to the availability of nutrient solutions. This study aimed to examine how various fertilizer formulations affect the macronutrient (P, K, Ca, Mg, S) and micronutrient (Fe, Zn, Mn, Cu, B) content of hydroponically grown lettuce plants. A completely randomized design (CRD) was employed, and the Wet Digestion Method was used to prepare dry plant samples by breaking them down with a mixture of strong acids and heat. Nutrient concentrations were then analyzed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Statistical analysis of the nutrient data was performed using ANOVA to identify significant differences between treatments. The results indicated that the AB fertilizer and the O38 treatment were the most effective in increasing the majority of nutrients in the plants. Fertilizers with the highest phosphorus content were observed in the AB and O38 treatments, while the highest potassium content was found in the AB and O39 treatments. The highest calcium (Ca) and magnesium (Mg) levels were also recorded in the O38 treatment, highlighting the formulation's efficiency in supplying macronutrients. Regarding micronutrients, the highest iron (Fe) content was detected in the O37 treatment, whereas the highest zinc (Zn), copper (Cu), and boron (B) contents were found in the AB treatment. This study demonstrated the superiority of the AB fertilizer, which performed best and most consistently. However, the O38 formulation shows potential as a future alternative to commercial AB fertilizers, pending further improvements.

Keywords: Analysis of Nutrients, Efficiency of Nutrient Absorption, Macro, Micro, Solution Nutrition

1. Introduction

The development of modern agricultural technology has led to innovative cultivation methods to address challenges such as limited land availability, declining soil fertility, and the increasing demand for food driven by population growth. One increasingly popular method is hydroponics, a technique for growing plants without soil that uses nutrient solutions as the primary source of nutrients. According to Swastika et al. (2018), as cited in Setiawan (2018), hydroponics is a suitable planting system for overcoming land limitations, in which soil is not used; instead, water, sunlight, and carefully managed nutrients are controlled to support plant growth.

Etymologically, the term, from the Greek words "hydros" (water) and "ponos" (work), can be interpreted as a method of planting that uses water as the primary medium. This system allows farmers to precisely control the use of water, nutrients, and environmental factors (Friday et al., 2025). Hydroponics is widely used in horticultural cultivation, especially in urban areas, because it can produce plants with uniform quality and hygiene and greater land-use efficiency.

One of the main commodities in hydroponics is leafy vegetables, especially lettuce (*Lactuca sativa* L.), which has a short harvest cycle, high market demand, and contains important nutrients for consumer health. Lettuce is usually consumed fresh as a raw vegetable. It contains various nutrients, such as fiber, vitamin A, and minerals (Romalasari and Sobari, 2019).

Lettuce is one of the vegetables with a high economic

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value. Many countries, including Malaysia, grow lettuce as one of the results of farm-fresh produce. Malaysian lettuce exports worth US $17,838 million in 2019 show the importance of lettuce to many countries. Production of Malaysian lettuce in 2020 reached 54,583.69 metric tons, with a market estimated at RM141,917.60. Production of Malaysian lettuce covers an area of 3,172.65 hectares, with part of it planted in Pahang, which has an area of 2,536.52 hectares. In 2021, the number of production hectares increased to 58,677 hectares, and the harvest area increased to 3,470 hectares, indicating improved production compared to two years previously (Ghazali et al., 2023).

Even though the prospects for own cultivation are promising, cultivation in hydroponics faces several challenges. One of the main constraints is the high cost of start-up for development infrastructure, such as rack plant, pumps, tanks, water circulation systems, and pH and EC sensors. Cost is very difficult for a farmer at this scale. Additionally, the yield harvest often varies depending on the nutrient formulation used (Kristianto et al., 2023). Because every type of fertilizer hydroponics impacts plant growth and quality differently, many farmers have difficulty finding the proper composition. Nutritional imbalance can also occur if a farmer relies on a solution-based, ready-to-use nutrition product without understanding nutrient balance, which can affect the quality of the results. Problems like technical issues (pH and EC instability) and intensive monitoring also add complexity to the system.

Nutrition is very important for growth and development in plant hydroponics. Disadvantages and excess nutrition will negatively impact plants. The quality of results in plant hydroponics is greatly influenced by nutrient dosage, as nutrients provide the main supply of plants' water and mineral needs (Setiawan, 2018).

In a hydroponic system, all macro (N, P, K, Ca, Mg, S) and micro (Fe, Zn, Mn, Cu, B, Mo) nutrients must be available in a balanced composition for optimal absorption. Nutrient solution compounding, concentration regulation, pH monitoring, and electrical conductivity (EC) control are all part of its management to ensure optimal nutrient absorption. If nutrient levels are not controlled during hydroponic lettuce growth, nitrate accumulation can increase. Yields and profits from hydroponic lettuce plants can be reduced if they do not receive sufficient nutrients (Frasetya et al., 2018). In Malaysia, urban farming practices such as hydroponics, fertigation, and vertical farming are still relatively new. This system uses inorganic fertilizer, locally called AB mixed nutrition (Sanusi et al., 2024). To provide nutrition to hydroponic plants, farmers usually use AB Mix chemical fertilizer, a mixture of fertilizers A and B containing macro- and micro-nutrients, as well as sulfate and phosphate. This fertilizer is practical to use, but is relatively expensive and may cause side effects if used excessively (Jarho, 2018).

In the study by Zhang et al. (2025), statistical methods were used to determine the optimal NPK ratio in a closed hydroponic system. The results show that the ratio N:P: K = 3:1:2 produces the highest chlorophyll level and improves nitrogen absorption efficiency by up to 19% compared to the standard ratio.

Next, in the research, Wu et al. (2025) analyze the connection between variation in NPK solutions and photosynthesis and nutrient efficiency in plants. The results show that nitrogen imbalance can reduce photosynthetic activity by up to 14%, while potassium deficiency can decrease chlorophyll levels by up to 22%. In the research, the first thing that was done was a comparative analysis of the influence of various fertilizer formulations on the composition of nutrients in vegetables. Leafy vegetables are still very limited.

Therefore, this research aims to evaluate and compare the macronutrient (P, K, Ca, Mg, S) and micronutrient (Fe, Zn, Mn, Cu, B) content in lettuce hydroponically cultivated with various fertilizer formulations. Additionally, this study intends to identify the most efficient fertilizer formulation to enhance plant yield while optimizing nutrient use.

2. Material and Methods

2.1. Place and Time

Study This was carried out in the laboratory Steel Technology, Research Center Soil, Water, and Steel Science at the Institute Research and Progress Malaysian Agriculture (MARDI), Serdang, Selangor, Malaysia (2.983392.101.700652) and is at an altitude of ± 36 meters above sea level (masl). The activities study takes place from September 23, 2025, to October 3, 2025.

2.2. Implementation Study

Study this use of hydroponic cultivation with a number of treatment formulations of fertilizer. The test plants used are lettuce (*Lactuca sativa* L.), and the seeds used are premium brand lettuce seeds from Crop Power, which are sown for 2 weeks. After that, the seeds were moved to reservoir hydroponics, with the EC gradually increased each week (1.0–1.5 μS/cm). Administration fertilizer done in accordance with Table 1.

Table 1. Treatment and Type Fertilizers Used in Study

Treatment Code	Type Fertilizer	Form
O36	NPK	Liquid
O37	NPK + Micro Nutrients	Liquid
O38	NPK + Micro Nutrients	Tablet
O39	NPK + Micro Nutrients	Liquid
AB (Market) Commercial)	AB Mix Fertilizer (commercial) market)	Liquid

The fertilizer formulation for the O36–O39 treatment has been developed by MARDI since 2021. The difference with commercial AB fertilizer is that the MARDI formulation does not separate into solutions A and B. This result is caused by materials that are not compatible with the standard used, with the nature of the materials, and with each other, and do not form sediment, even when mixed at high concentrations, unlike AB fertilizer on the market.

This O 36–O39 formulation was developed through MARDI research using project funds from the 12th Malaysian Draft (RMK12-P515). When this formulation is still in the research stage and not yet marketed commercially. Meanwhile, AB fertilizer available on the market was also tested. In this study, this is the comparator or control.

Plant lettuce harvested at 45 days old after planting. Sample study in the form of plant dry, obtained with method clean fresh plant results harvest, then dried in an oven at 60 ° C for 2–3 days until reach condition dry perfect. After drying, the weight of the dry plant was recorded for get biomass datadry . Next, the sample is dried and ground using a DFY-300 type grinder machine to obtain a shaped powder, then sieved to obtain a smooth, uniform powder. The implementation diagram study is as follows:

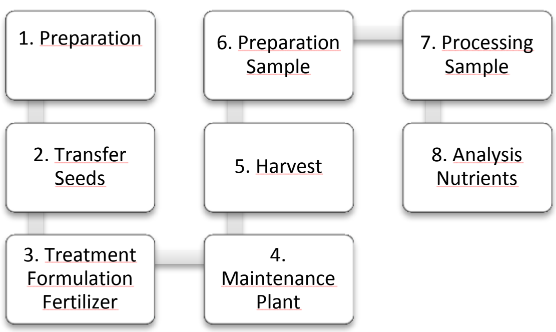

Figure 1. Research flow diagram

2.3. Materials and tools

Materials and tools used in the study consist of activities in the field and in the laboratory. In these activities, the field and the materials used include seed premium lettuce (*Lactuca sativa* L.), fertilizer, and water, while the tools used include seed trays, conductometers, glasses, measuring cups, and beakers. In the activity laboratory, the materials used are a sample of plant lettuce (*Lactuca sativa* L.), dry, concentrated nitric acid (HNO_3), and concentrated hydrochloric acid (HCl). The tools used include a covering paper filter 110 mm diameter, tube digestion, digestive block along with the stand, the analytical scale, spatula, funnel strain, pumpkin measuring 100 mL capacity, bottle samples, as well as a glass measure.

2.4. Research methods

In this research, the research method used was the Completely Randomized Design Method (CRD). In this research, the Wet Digestion method was also carried out, namely a wet destruction method that uses a mixture of strong acid and heating to destroy dry plant samples. This process aims to break down organic tissue into a simple solution that is easy to analyze, so that nutrients that were originally bound in plant tissue can be converted into free ions. Thus, the content of macro nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium, as well as other microelements, can be measured using analytical instruments such as AAS, Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), or a spectrophotometer.

In this study, the Wet Digestion procedure was carried out by weighing 1 g of dried lettuce plant samples. The sample was then added to 10 mL of concentrated nitric acid (HNO_3) and left overnight. Next, the sample was digested on a digestion block at 110 °C for approximately 2 hours, or until the yellow smoke disappeared and the solution became clear. After that, the sample was cooled, and 5 mL of concentrated hydrochloric acid (HCl) was added. The digestion continued for about 30 minutes until the solution became clear again. The solution obtained was cooled in a 100 mL measuring flask, then diluted with distilled water until it reached the limit mark. The solution was transferred and filtered into a sample bottle and then sent to the laboratory for analysis using an ICP-OES (Inductively Coupled Plasma–Optical Emission Spectrometry) instrument to determine the levels or concentrations of macronutrients such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), as well as micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and boron (B) in lettuce plants cultivated hydroponically with various fertilizer formulations. This analysis was conducted to determine the extent to which each nutrient combination affects plant nutrient absorption. This analysis is important for understanding the optimal nutritional requirements for the growth and quality of hydroponic lettuce yields, so it can be used to design more efficient and balanced fertilizer formulations.

Nutrient uptake was determined by multiplying the nutrient concentration by the dry weight of each plant part. Nutrient uptake data in lettuce plants were analyzed using analysis of variance (ANOVA). The mean values for each treatment were then compared using a multiple-comparison test based on the Least Significant Difference (LSD) method at a significance level of $p \leq 0.05$. All statistical analyses were conducted using SAS software version 9.4.

3. Results and Discussion

Content macro and micronutrients in lettuce shown in

Figure 1 and 2.

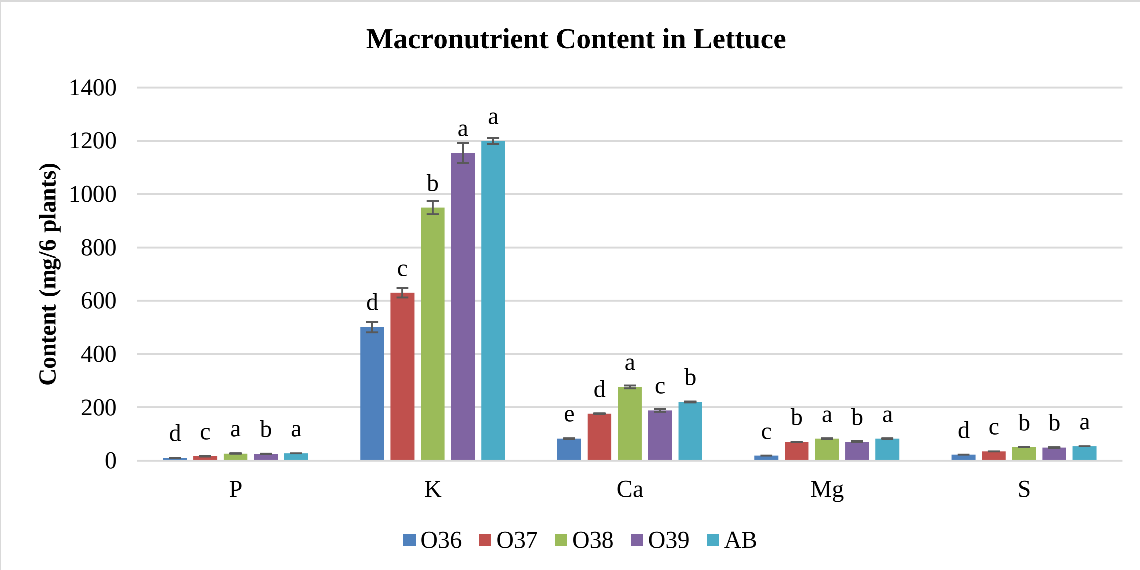

Figure 1. Chart Contents: Macronutrients in Nutrient Analysis Results. Average value with different letters on each nutrient shows a significant difference at the p≤0.05 level based on the Least Significant Difference (LSD) test.

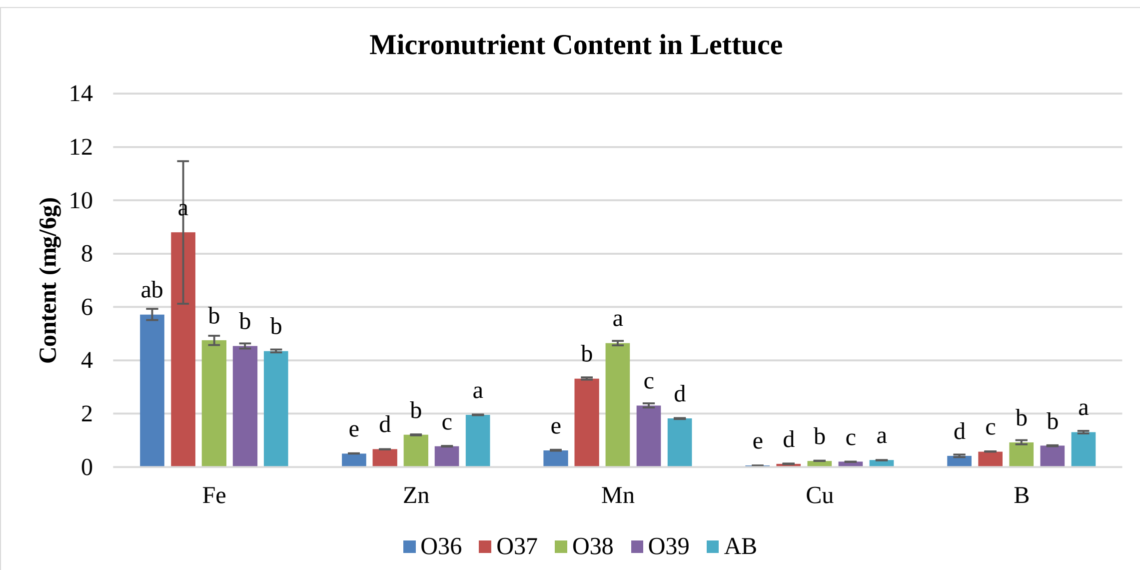

Figure 2. Chart Contents Micronutrients in Nutrient Analysis Results. Average value with different letters on each nutrient shows a significant difference at the p≤0.05 level based on the Least Significant Difference (LSD) test.

The results of the statistical analysis in Table 2 show that the highest phosphorus (P) content in hydroponic lettuce plants was found in the AB (27.54) and O38 (27.01) treatments, which were not significantly different, indicating that both were most effective in increasing plant phosphorus (P) uptake. Treatment O39 (25.31) was still considered good but lower, while O37 (16.82) and O36 (10.56), which only used NPK, showed the lowest results. This indicates that the use of AB fertilizer and a combination of nutrients in O38 is more efficient in providing phosphorus elements than single NPK (O36) in the lettuce hydroponic system.

The high phosphorus value could also be due to better root absorption efficiency. This result is in line with the findings (Selem et al., 2022), which showed that increasing phosphorus concentration in the hydroponic solution proportionally increases P accumulation in plant tissue, especially during the vegetative phase.

Based on the data in the table, the Potassium (K) content shows significant variation between treatments, with the highest being in the AB treatment (1199.57) and the lowest in the O36 treatment (501.76). This matter shows that giving different concentrations of nutrients or variations in the system hydroponics (for example, differences in solution composition or electrical conductivity (EC) level) has an effect on the direct accumulation of K in the network plant lettuce.

Table 2. Phosphorus (P) Contents

t Grouping	Mean	N	GROUP
A	27.5400 ± 0.23	6	ab
A	27.0083 ± 0.85	6	O38
B	25.3150 ± 0.69	6	O39
C	16.8233 ± 0.59	6	O37
D	10.5650 ± 0.29	6	O36

Table 3. Contents Potassium (K)

t Grouping	Mean	N	GROUP
A	1199.57 ± 10.73	6	ab
A	1154.82 ± 37.95	6	O39
B	949.77 ± 24.62	6	O38
C	630.40 ± 17.80	6	O37
D	501.76 ± 20.1	6	O36

Potassium is a macronutrient that plays an important role in regulating osmotic pressure, enzyme activity, photosynthesis, and ion balance in plants. In system hydroponics, where nutrients are fully available in dissolved ionic form, K availability is largely determined by solution concentration, nutrient stability, and pH. A study (Liu et al., 2025) shows that increasing K concentration in solution hydroponics can increase vegetative growth and water-use efficiency without causing declines, provided that the ratio of nitrogen to calcium is balanced.

Table 4. Calcium (Ca) Contents

t Grouping	Mean	N	GROUP
A	276.877 ± 5.20	6	O38
B	220.247 ± 2.06	6	ab
C	188.508 ± 4.65	6	O39
D	176.443 ± 1.37	6	O37
E	83.175 ± 1.23	6	O36

Based on the results of the statistical analysis presented in Table 4, the O38 (NPK + Trace Element Tablet) treatment showed the highest calcium content, which was significantly higher (276,877). This advantage is likely due to the high calcium content of the tablet fertilizer and the type of raw material used. The materials used are different from AB fertilizer because they can be mixed directly, unlike AB fertilizer. However, this fertilizer formulation is MARDI's secret. AB fertilizer (220.247) and other liquid formulations (O39 and O37) show good results, but cannot match the effectiveness of tablet fertilizer. Treatment O36 (NPK Only) was at the bottom (83.175). This finding proves that the basic NPK formula fails to provide sufficient Calcium.

Table 5. Magnesium (Mg) Contents

t Grouping	Mean	N	GROUP
A	82.730 ± 0.99	6	ab
A	82.402 ± 1.47	6	O38
B	71.458 ± 1.36	6	O39
B	70.945 ± 0.25	6	O37
C	19.152 ± 0.10	6	O36

Analysis in Table 5 shows that the fertilizer treatment significantly affects the amount of Magnesium (Mg) the hydroponic lettuce can absorb. AB (82.73g) and O38 (NPK + Treatment element Tablet) (82.40g) were superior and comparable. These two formulas proved to be the best in providing Mg, with the tablet treatment (O38) once again demonstrating effectiveness equivalent to the standard hydroponic formula (AB). O39 (71.45g) and O37 (70.94g) achieved adequate Mg levels, but their performance was still slightly below Group A. Treatment O36 (NPK Only) was far and away the lowest (19.15g). This figure confirms the presence of severe Magnesium deficiency in lettuce given only basic NPK. Treatment O36 (19.15) shows significant Mg deficiency, possibly a consequence of the lack of additional Mg from outside, given the low NPK content. According to Misskire *et al.* (2019), Mg deficiency causes a 35% decline in photosynthesis and a redistribution of nutrients from older to younger leaves.

Table 6. Contents Sulfur (S)

t Grouping	Mean	N	Treatment
A	53.833 ± 0.22	6	ab
B	50.738 ± 0.82	6	O38
B	49.485 ± 1.35	6	O39
C	34.605 ± 0.22	6	O37
D	22.923 ± 0.46	6	O36

The test results in Table 6 show that adding fertilizer supplements is crucial for increasing lettuce sulfur (S) content. AB fertilizer led the way with the highest sulfur content (53.833%), confirming its effectiveness in providing S, a vital nutrient for protein formation. Treatments O38 (Tablet) (50.738) and O39 (Liquid) (49.485) showed almost equivalent performance to AB, indicating that the Trace Element formula successfully included adequate amounts of Sulfur. O37 showed a significant decrease (34,605), probably due to compositional variations in its formula. O36 (NPK Only) was at the lowest level (22.923). This finding demonstrates that pure NPK fertilizer is very low in sulfur, potentially leading to plant deficiencies. O36 has the lowest sulfur content because conventional NPK fertilizers seldom contain significant amounts of sulfur.

Decline in content can indicate sulfur deficiency due to an ion imbalance or low electrical conductivity (EC) in solution nutrition. A study (Grishina et al., 2021) found that lettuce grown hydroponically in a solution with sulfur deficiency showed a decline in antioxidant activity of up to 40% and a decline in leaf protein content.

Table 7. Contents Iron (Fe)

t Grouping		Mean	N	GROUP
	A	8,795 ± 2.67	6	O37
	A	5,717 ± 0.21	6	O36
B		4,755 ± 0.17	6	O38
B		4,538 ± 0.10	6	O39
B		4.353 ± 0.05	6	ab

Based on table 7 above show that highest Fe content obtained in treatment O37 (NPK + liquid trace elements) was 8,795, while Treatment O36 (NPK only), O38 (NPK + trace element tablets), O39 (NPK + liquid trace element) and AB fertilizer showed higher Fe content low, ranging between 4.35–5.72 based on statistical tests, treatment O37 is included different group A real from treatment others (group B). The Fe content in the O36 treatment is classified as No normal because micronutrients are included in the formulation. The Fe content possibility originates from the tap water source used to make the solution fertilizer, as indicated by the high Fe content in the O37 treatment. According to (2019), Fe concentration in the hydroponic system is highly dependent on water quality, solution pH, and Fe form. Fe chelate used.

Analysis in Table 8 shows that the standard formula of AB Fertilizer demonstrates dominance in providing zinc, with the highest content of 1.96333 (Group A). This superiority of AB Fertilizer confirms that its formulation is specifically designed to ensure the adequacy of microelements. O38 (NPK + TE Tablet) (1.21167, Group B) ranks second. Although effective, the Zn content in this tablet is significantly lower than that of AB Fertilizer. O39 (NPK + TE Liquid) (0.78000, Group C) and O37 (NPK + TE Liquid) (0.67167, Group D) are below O38. This gradual decrease indicates a significant difference in Zn concentration among the Trace Element fertilizer variants, where the O39 liquid fertilizer is slightly superior. Treatment O36 (NPK Only) produced the lowest zinc content, at only 0.50833 (Group E). This figure indicates that the basic NPK formula is insufficient to meet zinc (Zn) requirements.

Table 8. Contents Zinc (Zn)

t Grouping	Mean	N	GROUP
A	1.96333 ± 0.02	6	ab
B	1.21167 ± 0.02	6	O38
C	0.78000 ± 0.02	6	O39
D	0.67167 ± 0.01	6	O37
E	0.50833 ± 0.01	6	O36

Table 9. Contents Manganese (Mn)

t Grouping	Mean	N	GROUP
A	4.65000 ± 0.06	6	O38
B	3.32000 ± 0.04	6	O37
C	2.31000 ± 0.07	6	O39
D	1.82333 ± 0.02	6	ab
E	0.62833 ± 0.02	6	O36

The results of the analysis in Table 9 show that the highest manganese (Mn) content was found in the O38 (NPK + trace element tablet) treatment at 4.65, whereas the lowest was in O36 (NPK only) at 0.63. This shows that the addition of an element micro can increase the availability and absorption of Mn in lettuce hydroponics. O38 tablet fertilizer may contain a higher percentage of Mn, so that Mn content in grown lettuce with O38 treatment is also higher than with other fertilizers. Overall, the provision of trace elements has been shown to increase tissue Mn content, supporting photosynthesis and optimal growth (Przybysz et al., 2017).

The results of the analysis in Table 10 show that the highest Cu content was found in the treatment AB fertilizer (A = 0.2633), followed by NPK + TE Tablet (O38 = 0.2283), NPK + TE Liquid (O39 = 0.2000), NPK + TE (O37 = 0.1250), and the lowest in NPK Only (O36 = 0.0550). Cu levels in the treatment with additional trace elements show that the element given microdosed through fertilizer liquid or tablet can increase the availability and absorption of Cu by lettuce plants.

Treatment AB fertilizer produces the highest Cu content because it contains the microelements in an easily absorbed form. On the other hand, NPK treatment without additional trace elements (O36) has the lowest Cu content, with consequences of limited supply of the microelement. According to Dey *et al.* (2023), lettuce can optimally absorb Cu in a hydroponic system at levels up to the limit of safety without reduced growth.

Table 10. Contents Copper (Cu)

t Grouping	Mean	N	GROUP
A	0.263333 ± 0.00	6	ab
B	0.228333 ± 0.01	6	O38
C	0.200000 ± 0.00	6	O39
D	0.125000 ± 0.01	6	O37
E	0.055000 ± 0.00	6	O36

Table 11. Contents Boron (B)

t Grouping	Mean	N	GROUP
A	1.31333 ± 0.05	6	ab
B	0.93000 ± 0.07	6	O38
B	0.80333 ± 0.02	6	O39
C	0.58333 ± 0.01	6	O37
D	0.42333 ± 0.05	6	O36

Based on Table 11, the consecutive B contents from highest to lowest are AB fertilizer (A) = 1.3133, followed by NPK + trace element tablet (O38) = 0.9300, NPK + trace element liquid (O39) = 0.8033, NPK + TE liquid (O37) = 0.5833, and NPK only (O36) = 0.4233. This finding shows that adding trace elements increases the actual Boron content in network lettuce compared with NPK alone. AB fertilizer can provide Boron in more forms , more easily accessible, or at higher concentrations, so that plants with treatment can absorb more B at maximum. Treatment with trace element tablets also shows results tall approaching AB, while NPK treatment only (without additional Boron) indicates the lowest yield.

Research in Indonesia on Boron reflects the important role of B for plant growth, especially in division cells and in the growth of stems and leaves.

For example, in the study "The Influence of boron administration to growth and production of two melon varieties (Cucumis Melo L.) in the solid media hydroponics system" by Rahma et al. (2015), proper boron administration increases melon growth and production in the hydroponics system.

4. Conclusion

Based on plant analysis, lettuce fertilized with O38 had nutrient content nearly equivalent to that of lettuce fertilized with commercial AB fertilizer, with similar relative levels of P, Mg, and Fe. Additionally, the Ca and Mn content in lettuce treated with O38 was higher compared to lettuce fertilized with AB fertilizer. For other elements such as K, S, Zn, Cu, and B, the differences between the two treatments were minimal.

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