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Growth and Yield of Lettuce (*Lactuca sativa* L.) in a Hydroponic Wick System Using Two AB Mix Formulations Partially Substituted with Liquid Organic Fertilizer

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ABSTRACT

Reducing dependence on synthetic fertilizers is an important consideration in hydroponic production, particularly because commercial AB Mix formulations contribute substantially to production costs. Liquid organic fertilizer (LOF) may serve as a partial substitute because it supplies nutrients and plant growth-regulating compounds, although its nutrient concentration is generally lower than that of AB Mix. This study evaluated the response of lettuce to different proportions of LOF substituted for two AB Mix formulations and identified the substitution level that maintained satisfactory growth and yield in a hydroponic wick system. The experiment was conducted in Sidomulyo Village, Anggana District, Kutai Kartanegara Regency, East Kalimantan, from March to May 2024. A single-factor experiment was arranged in a randomized complete block design with seven replicates and two treatment series. The Goodplant series consisted of g_0 (100% Goodplant AB Mix), g_1 (75% AB Mix + 25% LOF), g_2 (50% AB Mix + 50% LOF), and g_3 (25% AB Mix + 75% LOF). The Meroke series consisted of m_0 (100% Meroke AB Mix), m_1 (75% AB Mix + 25% LOF), m_2 (50% AB Mix + 50% LOF), and m_3 (25% AB Mix + 75% LOF). Analysis of variance showed that nutrient substitution significantly affected lettuce growth and yield. The highest values for several yield-related traits were recorded under m0, including leaf width (11.66 cm), leaf length (18.51 cm), taproot length (27.00 cm), plant fresh weight (78.49 g), root fresh weight (5.85 g), and stem diameter (1.00 cm). Importantly, replacing 25% of AB Mix with LOF did not significantly reduce growth or yield compared with the corresponding 100% AB Mix treatments. Under the conditions of this study, LOF can therefore replace up to 25% of AB Mix in a lettuce wick-hydroponic system

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is widely consumed as a leafy vegetable and is valued for its nutritional properties. The crop contains vitamins A, K, and C, has a relatively low caloric content, and provides antioxidant compounds. Its increasing market demand, together with population growth and improvements in household income and welfare, creates an opportunity to expand lettuce production in Indonesia (Tintondp, 2015; Mujiono et al., 2017).

Hydroponic cultivation offers a practical option for producing lettuce where productive land is limited. Unlike conventional cultivation, hydroponic systems do not depend on soil as the main source of water and nutrients. Instead, nutrients are supplied directly through the irrigation solution, making the system suitable for areas where land availability and

soil conditions are limiting factors (Hayati, 2016). Among the available systems, wick hydroponics is particularly simple because it does not require an electric pump. The installation can be assembled from inexpensive and readily available materials, making it attractive for small-scale and urban production (Tintondp, 2015).

Plant nutrition is a key determinant of hydroponic performance. AB Mix is commonly used because it is formulated to provide the macro- and micronutrients required by plants. Goodplant AB Mix is one commercial formulation used by hydroponic growers, whereas other growers prepare nutrient solutions from water-soluble-grade fertilizers such as those marketed by PT Meroke Tetap Jaya. Although these formulations are effective, the cost of AB Mix can become a constraint for small-scale growers.

The continued use of synthetic fertilizers also raises concerns regarding environmental quality and potential effects associated with excessive fertilizer application (Thorat & More, 2022; Kumar & Keshar Dev, 2017). Partial substitution with liquid organic fertilizer (LOF) could provide an alternative strategy for reducing synthetic fertilizer use and lowering production costs. LOF is produced by decomposing organic materials, including plant residues and animal or human waste, and may contain macro- and micronutrients as well as compounds with plant growth-regulating activity (Hadisuwito, 2007; Nugroho, 2021). However, because the nutrient concentration of LOF is generally lower than that of formulated hydroponic fertilizers, LOF is unlikely to meet the complete nutritional requirements of hydroponically grown plants when used alone (Purnomo et al., 2015).

Consequently, the effectiveness of LOF depends on the proportion used in combination with AB Mix. An excessive replacement level may reduce nutrient availability and ultimately suppress plant growth, whereas a moderate substitution level may maintain adequate nutrition while reducing synthetic fertilizer input. The present study therefore examined two AB Mix formulations combined with several LOF substitution levels and evaluated their effects on lettuce growth and yield in a wick-hydroponic system.

METHODS

Plant Materials, Nutrient Sources, and Equipment

Batavia lettuce seeds were used as the plant material. Other materials included rockwool, a mixture of rice-husk charcoal and cocopeat, Fortune liquid organic fertilizer, rainwater, Goodplant AB Mix, and Meroke water-soluble-grade fertilizers (MerokeCALNIT, MerokeFLEX-G, MerokeMAP, and MerokeMAG-S). The hydroponic units were made from used 1,500-mL mineral-water bottles and equipped with 23.0 cm × 1.5 cm flannel wicks. Neem oil was used for pest management. The main equipment included seedling containers, measuring cylinders, buckets, a digital balance, plastic containers, sprayers, cutting tools, ruler, caliper, pH meter, TDS meter, labels, and documentation equipment.

Experimental Design and Treatments

A single-factor experiment was arranged in a randomized complete block design with seven replicates. Treatments were divided into two series according to the AB Mix formulation. The Goodplant series comprised g_0 (100% Goodplant AB Mix), g_1 (75% Goodplant AB Mix + 25% LOF), g_2 (50% Goodplant AB Mix + 50% LOF), and g_3 (25% Goodplant AB Mix + 75% LOF). The Meroke series comprised m_0 (100% Meroke AB Mix), m_1 (75% Meroke AB Mix + 25% LOF), m_2 (50% Meroke AB Mix + 50% LOF), and m_3 (25% Meroke AB Mix + 75% LOF).

Preparation of Nutrient Solutions

For Goodplant AB Mix, concentrates A and B were prepared separately. Each powder was dissolved in 3 L of rainwater and stirred until completely dissolved, after which rainwater was added to a final volume of 5 L. The concentrates were stored in closed plastic containers and diluted at 5 mL L^{-1} before use. Meroke AB Mix concentrates were prepared in the same manner. Concentrate A contained 500 g MerokeCALNIT, while concentrate B contained 220 g MerokeMAG-S, 650 g MerokeFLEX-G, and 30 g MerokeMAP (Fatiha et

al., 2022). The Meroke concentrates were diluted at 10 mL L^{-1} before application.

Seedling Production and Wick-Hydroponic Installation

Rockwool cubes measuring 2 cm × 2 cm were prepared with one planting hole per cube and moistened before sowing. One lettuce seed was placed in each hole. Seedlings received water for the first seven days and the respective nutrient solutions during the following seven days. The wick system used 1,500-mL used mineral-water bottles as combined planting and nutrient-reservoir units, with flannel serving as the wick.

The growing medium consisted of rice-husk charcoal mixed with cocopeat, with 20 g placed in the upper section of each unit. Goodplant AB Mix was diluted at 5 mL L^{-1}, Meroke AB Mix at 10 mL L^{-1}, and LOF at 10 mL L^{-1}. The AB Mix and LOF solutions were mixed according to the assigned treatment, and 700 mL of nutrient solution was added to each reservoir.

Transplanting and Crop Management

Seedlings were transplanted at 14 days after sowing into the prepared hydroponic units. Crop maintenance included replenishing the nutrient solution, cleaning the reservoirs, and monitoring pests and diseases. The nutrient solution was completely replaced at 13 and 25 days after transplanting (DAT), while the reservoir volume was restored to 700 mL every four days. pH and total dissolved solids (TDS) were measured during nutrient replenishment and replacement.

Pests and diseased plant parts were removed manually. When necessary, commercial neem oil was applied according to the concentration and application interval stated on the product label. Plants were harvested at 30 DAT by removing the entire plant together with its roots.

Growth and Yield Measurements

Shoot height was measured at 1, 2, 3, and 4 weeks after transplanting (WAT). Leaf number was recorded at 2, 3, and 4 WAT. At harvest, leaf width was measured at the widest point of the widest leaf, and leaf length was measured along the longest leaf. Taproot length was measured from the root base to the root tip. Plant fresh weight and root fresh weight were determined using an analytical balance. Stem length was measured from the stem base to the growing point, and stem diameter was measured at the widest part of the stem using a caliper.

Statistical Analysis

The data were analyzed using analysis of variance. When the analysis indicated a significant treatment effect, means were further compared using orthogonal contrasts. Seven contrasts were evaluated: k_1, Goodplant versus Meroke AB Mix (g_0–g_3 vs. m_0–m_3); k_2, 100% AB Mix versus 25% LOF substitution (g_0,m_0 vs. g_1,m_1); k_3, 100% AB Mix versus 50% LOF substitution (g_0,m_0 vs. g_2,m_2); k_4, 100% AB Mix versus 75% LOF substitution (g_0,m_0 vs. g_3,m_3); k_5, 25% versus 50% LOF substitution (g_1,m_1 vs. g_2,m_2); k_6, 25% versus 75% LOF substitution (g_1,m_1 vs. g_3,m_3); and k_7, 50% versus 75% LOF substitution (g_2,m_2 vs. g_3,m_3).

RESULTS AND DISCUSSION

The analysis of variance showed that replacing AB Mix with LOF significantly affected all measured growth and yield variables. The orthogonal contrast analysis revealed that the response depended on both the AB Mix formulation and the proportion of LOF used.

For shoot height at 1 WAT, Goodplant and Meroke differed highly significantly (k_1), whereas the 100% AB Mix treatments did not differ from the 25% or 50% LOF substitutions (k_2 and k_3). In contrast, the 75% LOF treatment differed highly significantly from the control (k_4). At 2–4 WAT, Goodplant and Meroke differed significantly, k_2 remained non-significant, and the comparisons involving 50% and 75% LOF substitution were significant to highly significant.

For leaf number, Goodplant and Meroke did not differ significantly. The 25% LOF substitution also remained comparable with the control, whereas higher substitution levels resulted in significant differences. Similar patterns were observed for leaf width, plant fresh weight, and stem length: the 25% LOF treatment was statistically comparable with the corresponding control, while 50% and 75% substitution produced significant reductions.

Leaf length, taproot length, root fresh weight, and stem diameter showed significant differences

between the Goodplant and Meroke formulations. Nevertheless, the 25% LOF substitution remained statistically comparable with 100% AB Mix, whereas the higher substitution levels generally resulted in significant differences.

Table 1. TDS and electrical conductivity (EC) of the nutrient solutions

Treatment	TDS (ppm)	EC (mS cm^{-1})
g_0	1328	2.656
g_1	1174	2.348
g_2	713	1.426
g_3	441	0.882
m_0	1645	3.290
m_1	1265	2.530
m_2	841	1.682
m_3	525	1.050

The nutrient concentration declined progressively as the proportion of LOF increased. The Meroke treatments consistently showed higher TDS and EC values than the corresponding Goodplant treatments.

Discussion

Shoot Height

The reduction in shoot height at higher LOF substitution levels is closely associated with the decline in nutrient concentration and EC. The TDS and EC measurements followed the same pattern as the treatment proportions, with the lowest values recorded at 75% LOF substitution. This relationship agrees with previous findings that nutrient concentration influences lettuce height (Rahman et al., 2023). The two AB Mix formulations differed during the early growth stage, but the difference was no longer significant at 2–4 WAT. The initial response may be related to differences in micronutrient availability. PT Meroke Tetap Jaya recommends MerokeVITAFLEX as a micronutrient source for vegetable crops (PT Meroke Tetap Jaya, 2024a, 2024b). Interestingly, the 25% LOF treatment maintained shoot height comparable with the 100% AB Mix treatment. A possible explanation is that the AB Mix still supplied sufficient mineral nutrients, while the LOF contributed additional nutrients and growth-regulating compounds. The beneficial role of growth regulators in vegetative development has also been reported in okra (Rachmawati & Machfudz, 2017).

Leaf Number

Leaf production responded significantly to nutrient substitution, indicating that the availability of nutrients in the solution influenced leaf initiation and expansion. This agrees with earlier work showing that nutrient concentration affects leaf number in lettuce (Rahman et al., 2023). Goodplant and Meroke produced similar leaf numbers, suggesting that both formulations supplied adequate nutrients for leaf development. The 25% LOF substitution also maintained leaf number at a level comparable with the control. At higher substitution rates, however, the decline in nutrient concentration may have limited leaf formation, particularly because nitrogen is essential for cell and tissue development (Nurdiana, 2022).

Leaf Width

Leaf width decreased as the proportion of LOF increased, which is consistent with the lower nutrient concentration of LOF compared with AB Mix. Similar responses have been reported when LOF was used to replace part of the AB Mix in mustard greens (Pangaribuan et al., 2023). Although Goodplant and Meroke did not differ significantly for leaf width, the Meroke treatment produced the highest mean value. This may reflect its greater nutrient concentration. Iron availability can also influence lettuce leaf

development (Wicaksono, 2021). The comparable performance of the 25% LOF treatment suggests that moderate substitution can maintain adequate mineral nutrition while potentially providing growth-regulating compounds. Cytokinins, for example, are involved in cell division, organ development, chlorophyll formation, and chloroplast development (Salisbury & Ross, 1992).

Leaf Length

The decline in leaf length at higher LOF substitution levels indicates that reducing the proportion of AB Mix eventually limited nutrient availability. This agrees with observations in mustard greens in which AB Mix substitution with LOF altered leaf development (Pangaribuan et al., 2023). Meroke produced longer leaves than Goodplant, which may be related to its higher nutrient concentration and the potassium supplied by MerokeFLEX-G. Potassium is involved in photosynthetic processes and the movement of photosynthates, thereby supporting leaf expansion (Radjiman, 2020; Salsabila et al., 2023). The 25% LOF treatment remained comparable with the control, suggesting that the remaining AB Mix supplied sufficient nutrients. This interpretation is consistent with previous work identifying 1,000 ppm as an effective nutrient concentration for lettuce (Wijaya & Fajriani, 2022).

Taproot Length

Taproot development was also sensitive to the proportion of AB Mix replaced by LOF. Because LOF contains lower concentrations of mineral nutrients, increasing its proportion reduced the nutrient supply available to the roots. A similar response was reported for mustard greens grown with partial AB Mix substitution (Pangaribuan et al., 2023). Root development may also have been influenced by growth-regulating compounds in the LOF. The longer roots observed with Meroke may be associated with its higher nutrient concentration, including calcium. Calcium contributes to cell division and elongation, root growth, and cell-wall integrity (Nurdiana, 2022). The 25% LOF treatment remained comparable with the control, possibly because the nutrient supply remained adequate and the LOF provided compounds with auxin-, cytokinin-, or gibberellin-like activity that can influence root development (Asra et al., 2020).

Plant Fresh Weight

Plant fresh weight declined markedly when the proportion of LOF exceeded 25%. The response is consistent with the reduction in nutrient concentration measured in the nutrient solutions. Similar effects have been reported when LOF was used as a partial substitute for AB Mix in mustard greens (Pangaribuan et al., 2023). Goodplant and Meroke produced statistically similar plant fresh weights, indicating that both formulations were capable of meeting the basic nutritional requirements of lettuce. Notably, the 25% LOF treatment was comparable with the control, and g1 even produced a slightly greater mean fresh weight than g_0. A similar response was reported by Marginingsih et al. (2018). Greater leaf development contributes to photosynthetic capacity and biomass accumulation, which can ultimately increase plant fresh weight.

Root Fresh Weight

Root fresh weight followed a pattern similar to plant fresh weight. Increasing LOF substitution reduced the concentration of mineral nutrients available to the root system, resulting in lower root biomass at the highest substitution level. Meroke produced heavier roots than Goodplant, possibly because of its higher nutrient concentration and the phosphorus supplied by MerokeFLEX-G and MerokeMAP. Phosphorus is important for root development and the formation of new roots (Tisdale et al., 1985). The absence of a significant difference between the 25% and 50% substitution treatments and their respective controls suggests that moderate substitution still provided sufficient nutrients for root development. Growth regulators and other compounds transported within the plant may also contribute to root formation (Manurung, 1987).

Stem Length

Stem length was significantly affected by LOF substitution, reflecting the changes in nutrient concentration. Goodplant and Meroke did not differ significantly, indicating that both formulations supplied adequate nutrients for stem development. The longest stem was recorded in g_1, and this treatment remained statistically comparable with the control. This result suggests that replacing a small proportion of AB Mix with LOF did not compromise nutrient supply and may have provided additional growth-regulating compounds. Calcium is associated with lettuce stem development (Suryantini et al., 2020), while auxin and gibberellin are known to promote cell and internode elongation (Asra et al., 2020; Fauziah, 2021).

Stem Diameter

Stem diameter decreased as the proportion of LOF increased. The response likely reflects the reduction in nutrient concentration, particularly nitrogen, which is important for vegetative growth. Meroke produced a greater stem diameter than Goodplant, consistent with the higher concentration of the Meroke nutrient solution. MerokeCALNIT, MerokeFLEX-G, and MerokeMAP provide nitrogen that supports leaf and stem development (Lingga, 2005). The 25% LOF treatment remained comparable with the control, indicating that the remaining AB Mix was sufficient to support normal stem development. Nutrient concentrations around 1,000 ppm have been reported to support lettuce growth effectively (Krestiani & Supriyo, 2022). The presence of growth-regulating compounds in LOF may also have contributed to stem thickening.

Table 2. Growth and Yield of Lettuce Under Different AB Mix–LOF Combinations

Treatment	Shoot height				Leaves				Leaf width (cm)	Leaf length (cm)	Taproot (cm)	Plant FW (g)	Root FW (g)	Stem length (cm)	Stem diameter (cm)
	1 WAT	2 WAT	3 WAT	4 WAT	1 WAT	2 WAT	3 WAT	4 WAT							
Anova	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
g_0	4.77	8.54	12.99	17.39	4.43	8.57	12.0	17.57	10.84	17.91	22.54	67.61	4.72	4.96	0.94
g_1	4.86	8.26	13.64	17.93	4.29	8.0	11.86	17.29	11.03	17.69	23.54	68.62	5.33	5.0	0.95
g_2	5.06	7.24	11.19	16.26	4.14	7.29	9.57	14.71	9.71	17.19	19.96	46.88	4.57	3.74	0.81
g_3	1.47	4.49	8.36	12.31	2.29	5.57	8.00	11.43	6.43	12.91	18.86	15.41	2.43	2.14	0.54
m_0	4.39	8.50	13.44	17.17	4.29	8.71	12.00	17.29	11.66	18.51	27.0	78.49	5.85	4.61	1.00
m_1	4.24	8.24	12.46	17.44	4.00	7.71	11.43	16.57	10.64	18.07	23.53	65.68	5.25	4.54	0.96
m_2	4.53	7.21	12.17	16.64	4.14	7.86	10.86	15.29	10.11	17.43	22.07	55.57	5.33	3.6	0.83
m_3	1.47	4.84	8.27	12.24	3.00	6.00	7.86	11.29	6.70	13.51	19.50	14.69	2.31	2.11	0.59

Note: FW = fresh weight; WAT = weeks after transplanting. The original analysis indicated a highly significant overall treatment effect for the measured variables. Orthogonal contrasts were used for mean comparisons.

CONCLUSION

The type of AB Mix and the proportion replaced by LOF both influenced lettuce growth and yield in the wick-hydroponic system. Meroke AB Mix without LOF produced the highest values for several yield-related traits, including leaf width, leaf length, taproot length, plant fresh weight, root fresh weight, and stem diameter. However, replacing 25% of either AB Mix formulation with LOF did not significantly reduce lettuce growth or yield compared with the corresponding 100% AB Mix treatment. These results indicate that a 25% LOF substitution can be used to reduce AB Mix input while maintaining lettuce performance under the experimental conditions.

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