



Effects of Organic Nutrient Solutions and Dissolved Oxygen Management on the Growth Performance of Hydroponic Lettuce (*Lactuca sativa* L. var. Green Rapid)

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ABSTRACT

This study evaluated the growth performance of lettuce (*Lactuca sativa* L. var. Green Rapid) as influenced by different organic nutrient solutions under aerated and non-aerated hydroponic systems. The experiment was conducted from October 24 to December 4, 2025 at the Greenhouse Experimental Area of Cebu Technological University-Barili Campus using a 2×7 factorial in a Randomized Complete Block Design with three replications. Treatments consisted of two aeration conditions (aerated and non-aerated) and seven nutrient solutions: pure water, probiotics, Indigenous Microorganisms (IMO), Fermented Fruit Juice (FFJ), Vermitea, Fish Amino Acid (FAA), and SNAP solution. Results revealed that aeration significantly improved plant height, leaf number, and biomass at later growth stages. SNAP solution consistently produced the highest growth performance across all parameters, significantly outperforming organic nutrient solutions. Moreover, significant interaction effects indicated that the combination of aeration and SNAP solution enhanced lettuce growth, particularly in plant height, leaf production, and shoot biomass. However, root-to-shoot ratios showed no significant differences among treatments, suggesting limited influence of treatments on biomass partitioning. Furthermore, the findings demonstrate that oxygen availability and nutrient completeness are critical factors in hydroponic lettuce production. While organic nutrient solutions showed moderate performance, they were less effective compared to SNAP solution, particularly under non-aerated conditions.

Keywords: Lettuce, Hydroponics, Aeration, Organic Nutrients, SNAP, Growth Performance 17

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is one of the most widely consumed leafy vegetables worldwide because of its high nutritional value, antioxidant properties, and short production cycle [37] [39]. In the Philippines, demand for fresh and nutritious vegetables has steadily increased, thereby enhancing the importance of lettuce production. However, conventional soil-based cultivation is frequently constrained by limited arable land, soil-borne diseases, nutrient depletion, and environmental stresses that adversely affect crop productivity [57] [60] [25].

Consequently, hydroponic cultivation has emerged as a sustainable alternative to conventional farming by enabling soilless crop production with precise control of water and nutrient supply [12] [29]. Moreover, hydroponic systems improve resource-use efficiency, reduce water consumption, and allow year-round vegetable production in areas with limited agricultural land [31] [42]. Among leafy vegetables, lettuce is particularly suitable for hydroponic cultivation because of its rapid growth, high market demand, and adaptability to soilless environments [46] [52].

Nevertheless, the success of hydroponic production largely depends on root-zone conditions, particularly dissolved oxygen availability. Adequate oxygen levels are essential for root respiration, nutrient absorption, and overall plant development [20]. In contrast, oxygen deficiency can impair root metabolism, restrict nutrient uptake, and ultimately reduce plant growth and yield [36]. Accordingly, several studies have reported that



aeration significantly enhances lettuce growth, biomass accumulation, nutrient uptake, and crop quality under hydroponic systems [25] [7] [47].

Furthermore, increasing environmental concerns and the rising cost of synthetic fertilizers have stimulated interest in organic nutrient solutions for hydroponic production. Specifically, Indigenous Microorganisms (IMO), Fish Amino Acid (FAA), Fermented Fruit Juice (FFJ), Vermitea, and probiotics have gained attention because they supply nutrients, beneficial microorganisms, and plant growth-promoting compounds [27] [28]. For instance, IMO enhances nutrient cycling and microbial activity, while FAA provides amino acids and nitrogen necessary for vegetative growth [30] [69]. Likewise, FFJ and Vermitea have been reported to improve nutrient availability, plant vigor, and crop performance [8] [51] [4].

Although previous studies have demonstrated the potential of organic nutrient sources in hydroponic systems [1] [2] [6], information regarding their effectiveness under varying aeration conditions remains limited. More importantly, the interaction between organic nutrient solutions and dissolved oxygen availability has not been sufficiently explored in hydroponic lettuce production.

Therefore, this study was conducted to evaluate the growth performance of lettuce (*Lactuca sativa* L. var. Green Rapid) supplied with different organic nutrient solutions under aerated and non-aerated hydroponic systems. Specifically, it aimed to determine the effects of nutrient source and aeration on lettuce growth and identify sustainable nutrient management strategies for hydroponic production.

MATERIAL AND METHODS

Location and Duration of the Study

The study was conducted from October 24, 2025 to December 4, 2025 at the Greenhouse Experimental Area of Cebu Technological University – Barili Campus, Cagay, Barili, Cebu, Philippines. The experimental area was protected with a greenhouse structure to minimize the effects of excessive rainfall, pests, and fluctuating environmental conditions during the conduct of the study.

Experimental Design

The study was conducted using a 2×7 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with three replications. The experimental design consisted of two factors: aeration system and nutrient solution treatments. Factor A involved two hydroponic oxygenation conditions, namely non-aerated hydroponic system (A0) and aerated hydroponic system (A1). Factor B consisted of seven nutrient-solution treatments: T0 – pure water (control), T1 – probiotics, T2 – Indigenous Microorganisms (IMO), T3 – Fermented Fruit Juice (FFJ), T4 – Vermitea, T5 – Fish Amino Acid (FAA), and T6 – Simple Nutrient Addition Program (SNAP) solution. Each experimental unit contained eight lettuce plants, giving a total of 336 experimental plants used in the study.

Experimental Setup and Crop Establishment

The experiment was carried out under controlled greenhouse conditions using styrofoam box hydroponic systems. Each styrofoam box measured approximately 60 cm $\times$ 40 cm and served as the nutrient reservoir for the lettuce plants. Holes were uniformly spaced on the Styrofoam cover to accommodate plastic cups containing coco peat as support medium for the seedlings.

Lettuce (*Lactuca sativa* L. var. Green Rapid) seedlings with 2–3 fully developed true leaves were transplanted individually into the hydroponic setup.

Each hydroponic container was supplied with four liters of nutrient solution according to the assigned treatment. For the aerated treatments, dissolved oxygen was continuously supplied using aquarium air pumps connected to air stones to enhance oxygen availability within the root zone. The non-aerated treatments received no supplemental aeration.



Nutrient solutions were replenished regularly to maintain sufficient solution volume throughout 2.3.1.

Nutrient-Solution Preparation and Application. The nutrient solutions used in the study were pure water, probiotics, Indigenous Microorganisms (IMO), Fermented Fruit Juice (FFJ), Vermitea, Fish Amino Acid (FAA), and Simple Nutrient Addition Program (SNAP) solution. Each solution was assigned to the appropriate treatment before it was placed in the experimental containers. The solutions were applied according to the treatment plan and were replenished when necessary to keep the containers supplied during the growing period. The original experimental records available for this revision do not contain complete recipes, preparation ratios, dilution rates, or laboratory measurements of nutrient concentration. These details are therefore not added or estimated in this revision. the experimental period.

Data Gathered

Growth and physiological parameters of lettuce were evaluated weekly and at harvest. Plant height (cm) was measured from the base of the plant to the tip of the tallest leaf. The number of leaves per plant was determined by counting fully expanded leaves. Shoot length (cm), leaf length and width (cm), and root length (cm) were measured using a ruler or measuring tape.

Biomass accumulation was assessed by obtaining the fresh root weight and shoot weight (g) using a digital weighing scale immediately after harvest. Root-shoot ratio and shoot-root ratio were computed to determine biomass partitioning and growth efficiency of the plants under different nutrient solutions and aeration systems.

Statistical Analysis

All data collected were subjected to Analysis of Variance (ANOVA) appropriate for a two-factor factorial RCBD using Statistix 10 statistical software. The analysis was performed to determine the main effects of aeration and nutrient solution treatments, as well as their interaction effects on the growth and physiological performance of lettuce. Treatment means exhibiting significant differences were further compared using Tukey's Honestly Significant Difference

(HSD) Test at a 5% level of significance.

RESULTS AND DISCUSSION

Plant Height of Lettuce

Table 1 showed the height of lettuce in response to the different nutrient solutions applied under aerated and non-aerated hydroponic system. There was no significant difference on its height at week 1 of observation. The results also show that the growth response of lettuce either in aerated or non-aerated hydroponic system showed no significant difference from week 1 to week 3. However, application of aeration (A1) influenced the height of lettuce better than A0 (Non-Aerated Hydroponics) as observed at week 4 and week 5.

Table 1. Weekly height (cm) of lettuce plants influenced with the application of different organic solutions under aerated and non-aerated hydroponic system

Treatment	Week No.				
	1	2	3	4	5
Factor A					
A0 – Non-Aerated	8.87	11.11	12.44	13.74 ^b	17.44 ^b



A1 - Aerated	9.02	10.91	12.42	15.57 ^a	18.84 ^a
Factor B					
T0 – Pure Water	9.06	11.22 ^b	12.67 ^b	14.42 ^b	18.79 ^b
T1 – Probiotics	8.89	10.69 ^b	10.99 ^b	13.66 ^b	15.97 ^b
T2 – Indigenous Microorganism	9.13	10.80 ^b	11.62 ^b	13.92 ^b	17.01 ^b
T3 – Fermented Fruit Juice	8.87	10.28 ^b	11.13 ^b	13.66 ^b	15.91 ^b
T4 – Vermitea	8.25	09.83 ^b	11.21 ^b	12.54 ^b	16.84 ^b
T5 – Fish Amino Acid	8.84	10.38 ^b	11.97 ^b	14.42 ^b	16.99 ^b
T6 – SNAP Solution	9.57	13.85 ^a	17.39 ^a	19.97 ^a	25.46 ^a
A X B					
A0T0	9.49	11.82 ^a _b _c	13.22 ^{bc}	14.70 ^{bc} _d	19.29 ^b _c
A0T1	8.99	10.97 ^{bc}	11.35 ^c	12.89 ^{cd}	16.50 ^c
A0T2	8.72	10.50 ^{bc}	10.92 ^c	11.67 ^d	14.58 ^c
A0T3	9.06	10.92 ^{bc}	11.42 ^c	12.12 ^{cd}	14.61 ^c
A0T4	8.08	09.10 ^c	11.26 ^c	12.46 ^{cd}	16.1 ^c
A0T5	8.37	09.75 ^c	10.39 ^c	11.78 ^d	14.16 ^c
A0T6	9.40	14.71 ^a	18.52 ^a	20.58 ^a	26.52 ^a
A1T0	8.99	10.61 ^{bc}	12.12 ^c	14.13 ^{bc} _d	18.29 ^b _c
A1T1	8.79	10.40 ^{bc}	10.64 ^c	14.43 ^{bc} _d	15.44 ^c
A1T2	9.55	11.11 ^{bc}	12.32 ^c	16.18 ^{ab} _{cd}	19.43 ^b _c
A1T3	8.69	09.64 ^c	11.42 ^c	15.20 ^{bc} _d	17.20 ^c
A1T4	8.42	10.56 ^{bc}	11.17 ^c	12.62 ^{cd}	17.58 ^c
A1T5	9.32	11.02 ^{bc}	13.55 ^{bc}	17.06 ^{ab} _c	19.53 ^b _c



A1T6	9.74	13.00 ^a _b	16.26 ^{ab}	19.36 ^{ab}	24.41 ^a _b
CV (%)	8.14	8.74	8.82	11.94	11.77
F-prob (A)	0.5143	0.5003	0.9455	0.0023	0.0427
F-prob (B)	0.1452	0.0000	0.0000	0.0000	0.0000
F-prob (A x B)	0.3325	0.0332	0.0058	0.0186	0.0313
Means within factor in each column followed by a common/without letter are not significantly different from each other at 5% level of significance using Tukey's Honestly Significant Difference (HSD) Test					

adaptation of lettuce plants to the hydroponic environment utilizing on the oxygen supplementation effectively in the root zone of hydroponic plants. Aerating the nutrient solution was associated with improved plant growth in certain species. Conversely, the absence of aeration was identified as a limiting factor affecting plant growth [16] [17].

A significant difference was observed in the application of different nutrient solutions as observed in weeks 2 to 5. In this experiment, the application of T6 Simple Nutrient Addition Program (SNAP) solution] consistently produced the highest plant height with a height of 13.85 cm, 17.39 cm, 19.97 cm and 25.64 cm respectively from weeks 2 to 5 compared to the application of the formulated organic concoctions which did not show any significant difference to the height of lettuce. [61] stated that the organic material provides nutrients and plant growth promoting substances, but they may not be sufficient for fast growing plants. For optimal growth, a more sophisticated combination of organic fertilizers could be investigated, or the organic hydroponic solutions could be enhanced by adding supplementary chemical nutrients [58]. Furthermore, SNAP has been rated as best in terms of overall marketability and sensory quality attributes compared to other commercial and organic alternatives [60].

The significant $A \times B$ interaction observed in weeks 2 to 5 further confirms that the combination of aeration and SNAP solution (A1T6) maximized plant height, indicating synergistic effects between oxygen availability and nutrient completeness. Although Non-aerated SNAP solution (A0T6) showed significantly higher height, A1T6 was comparable to it as well as the Pure water (A0T0) in week 2. In week 3, both A0T6 and A1T6 showed the highest height of lettuce.

Then at week 4, A0T6 was significantly the highest in height of 20.58 cm and A1T6 also showed comparable height to it alongside with the organic concoctions, Fish Amino Acid (A1T5) and Indigenous Microorganisms (A1T2) in aerated hydroponics with a height of 19.36 cm, 17.06 cm and 16.18 cm respectively. In week 5, only A0T6 still showed significantly higher height of 26.52 cm and only A1T6 was showing comparable results with a height of 24.41 cm.

The results suggest that aeration played an important role in nutrient absorption and utilization in hydroponically grown lettuce. Adequate dissolved oxygen supplied through aeration enhances root respiration and improves nutrient uptake efficiency, thereby promoting better plant growth. In this study, SNAP solution produced greater plant height under non-aerated conditions, while organic nutrient solutions performed comparably to SNAP solution when aeration was applied during Week 4. This indicates that aeration may have compensated for the relatively slower nutrient availability of organic solutions by improving oxygen supply and nutrient absorption in the root zone. [7] find out that aeration of the nutrient solution promoted plant growth, leaf K, P, and Mg, and water uptake, however, photosynthesis and transpiration rates were enhanced under non-aeration conditions. Decreasing N did not affect leaf N uptake and accumulation; however, decreasing K markedly decreased leaf P and K in aerated plants.

Oxygenation depends on the cultivation condition. Organic concoctions like Fish Amino Acid and Indigenous Microorganisms can achieve comparable results under aerated conditions, inorganic solutions remain more efficient at utilizing the supplemental oxygen for rapid growth.

Number of Leaves

Comparison between aerated and non-aerated hydroponics showed no significant difference in the number of leaves of lettuce except for week 5 where aeration showed greater number of leaves (Table 2). In terms of nutrient solution performance in hydroponics, the application of T6 showed the highest number of leaves of lettuce all throughout week 2 to week 5 with an average of 4.47, 4.92, 5.91 and 7.69 leaves respectively and no significant difference or variation was shown with the application of the organic concoctions. Studies confirm that SNAP significantly impacts plant height, leaf count, and overall yield, with optimal results often observed

Table 2. Number of leaves per week of lettuce in aerated and non-aerated hydroponic system applied with different organic solutions

Treatment	Week No.				
	1	2	3	4	5
Factor A					
A0 – Non-Aerated	3.52	3.87	4.01	4.74	5.72 ^b
A1 - Aerated	3.42	3.85	4.12	4.96	6.21 ^a
Factor B					
T0 – Pure Water	3.51	3.92 ^b	4.09 ^b	4.57 ^b	5.78 ^b
T1 – Probiotics	3.32	3.83 ^b	3.93 ^b	4.75 ^b	5.79 ^b
T2 – Indigenous Microorganism	3.59	3.75 ^b	4.06 ^b	4.72 ^b	5.77 ^b
T3 – Fermented Fruit Juice	3.46	3.77 ^b	3.86 ^b	4.77 ^b	5.57 ^b
T4 – Vermitea	3.52	3.52 ^b	3.75 ^b	4.40 ^b	5.58 ^b
T5 – Fish Amino Acid	3.48	3.77 ^b	3.86 ^b	4.84 ^b	5.61 ^b
T6 – SNAP Solution	3.42	4.47 ^a	4.92 ^a	5.91 ^a	7.69 ^a
A X B					
A0T0	3.71	3.98 ^{abc} _c	4.23	4.50 ^b	5.84 ^{bcde}
A0T1	3.17	3.86 ^{bc}	3.78	4.45 ^b	5.90 ^{bcde}
A0T2	3.75	3.58 ^{bc}	3.84	4.31 ^b	5.21 ^{cde}
A0T3	3.30	3.67 ^{bc}	3.67	4.42 ^b	4.58 ^c

A0T4	3.50	3.33 ^c	3.66	4.43 ^b	5.67 ^{bc} de
A0T5	3.59	3.96 ^{ab} _c	3.59	4.43 ^b	4.73 ^{de}
A0T6	3.63	4.73 ^a	5.31	6.64 ^a	8.14 ^a
A1T0	3.30	3.86 ^{bc}	3.95	4.65 ^b	5.71 ^{bc} de
A1T1	3.46	3.79 ^{bc}	4.10	5.04 ^b	5.67 ^{bc} de
A1T2	3.42	3.92 ^{ab} _c	4.29	5.13 ^b	6.33 ^{bc} de
A1T3	3.63	3.88 ^{bc}	4.04	5.13 ^b	6.56 ^{abc}
A1T4	3.54	3.71 ^{bc}	3.84	4.38 ^b	5.49 ^{bc} de
A1T5	3.38	3.59 ^{bc}	4.13	5.25 ^b	6.48 ^{ab} cd
A1T6	3.21	4.21 ^{ab}	4.54	5.17 ^b	7.23 ^{ab}
CV (%)	9.80	6.99	9.34	9.41	10.06
F-prob (A)	0.3427	0.794 6	0.3327	0.1261	0.0145
F-prob (B)	0.8815	0.000 1	0.0003	0.0002	0.0000
F-prob (A x B)	0.2677	0.049 6	0.0640	0.0020	0.0012
Means within factor in each column followed by a common/without letter are not significantly different from each other at 5% level of significance using Tukey's Honestly Significant Difference (HSD) Test					

at specific concentration levels [18]. The findings of [60] also concluded that using commercially available inorganic nutrient solution (SNAP and Masterblend) had the optimum level of nutrients for horticultural growth and development. According to [63] [65], the use of organic nutrient solutions showed poorer performance compared to chemical nutrient solutions.

As observed from Week 2 to Week 5, the interaction between aeration and nutrient solutions significantly influenced the number of lettuce leaves produced. In Week 2, the non-aerated SNAP solution treatment (A0T6) recorded the highest leaf number, although treatments such as aerated SNAP solution and Indigenous Microorganisms (A1T6 and A1T2), as well as non-aerated Pure Water and Fish Amino Acid (A0T0 and A0T5), showed comparable performance.

No significant differences were observed during Week 3. However, by Week 4, A0T6 significantly produced the highest number of leaves with a mean of 6.64 leaves, and this trend continued in Week 5. Nevertheless, aerated treatments including SNAP solution, Fish Amino Acid, and Fermented Fruit Juice (A1T6, A1T5, and A1T3) performed comparably.

These findings suggest that both oxygen availability and nutrient composition influenced vegetative growth and leaf initiation in hydroponic lettuce. An increase in the dissolved oxygen concentration and the temperature had significant effects on the plant height, transpiration rate (E), soluble protein and nitrate contents ($P < 0.05$), net photosynthetic rate (A), stomatal conductance (gsw), intercellular carbon dioxide concentration (Ci), leaf temperature (Tleaf), vitamin C content, yield and irrigation water use efficiency (IWUE) of lettuce ($P < 0.01$) [47].

Studies have shown that adequate aeration improves dissolved oxygen concentration in the root zone, enhancing nutrient absorption, root metabolism, and leaf development in lettuce grown hydroponically. Likewise, complete nutrient solutions containing readily available macro- and micronutrients promote rapid vegetative growth and increased leaf production.

Despite the higher transpiration and stomatic conductance in non-aerated plants, water uptake was higher in aerated plants. Non-aerated plants then exhibited decreased leaf K accumulation [7].

Length of Shoots

In terms of length of shoots, no significant difference was shown as observed in weeks 1 to 5 comparing between aerated and non-aerated hydroponics (Table 3). There was significant difference however in terms of nutrient solution performance. The application of the nutrient solutions showed comparable effects to the length of shoots with the application of SNAP solution (T6), Pure Water (T0), Probiotics (T1), Indigenous Microorganisms (T2) and Fermented Fruit Juice (T3) week 2. Then at week 3, only T0 and T6 showed comparable results compared to other treatments.

Table 3. Weekly length of shoots (cm) of lettuce influenced by different organic solutions in aerated and non-aerated hydroponic system

Treatment	Week No.				
	1	2	3	4	5
Factor A					
A0 – Non-Aerated	4.38	6.86	9.86	10.78	13.81
A1 - Aerated	4.58	7.11	9.92	11.58	15.08
Factor B					
T0 – Pure Water	5.05	6.80 ^{ab}	10.45 ^{ab}	11.30 ^b	14.69 ^b
T1 – Probiotics	4.19	6.86 ^{ab}	9.26 ^b	9.71 ^b	12.60 ^b
T2 – Indigenous Microorganism	3.97	7.23 ^{ab}	9.81 ^b	11.01 ^b	14.13 ^b
T3 – Fermented Fruit Juice	4.27	6.95 ^{ab}	9.11 ^b	10.88 ^b	12.56 ^b
T4 – Vermitea	4.72	6.36 ^b	9.31 ^b	9.96 ^b	13.18 ^b
T5 – Fish Amino Acid	4.03	6.13 ^b	8.94 ^b	10.24 ^b	13.27 ^b
T6 – SNAP Solution	5.14	8.55 ^a	12.36 ^a	15.18 ^a	20.70 ^a
A X B					

A0T0	5.27	7.11	10.71	11.82 ^{ab}	14.84 ^{bc}
A0T1	4.38	7.45	9.61	9.57 ^b	13.08 ^{bc}
A0T2	4.27	6.88	9.08	9.51 ^b	11.79 ^c
A0T3	3.74	6.60	9.19	8.94 ^b	11.50 ^c
A0T4	4.22	6.14	9.15	9.62 ^b	12.22 ^c
A0T5	3.72	5.38	8.38	8.77 ^b	11.25 ^c
A0T6	5.10	8.45	12.89	17.27 ^a	22.27 ^a
A1T0	4.83	6.49	10.19	10.78 ^b	14.84 ^{bc}
A1T1	4.01	6.27	8.92	9.84 ^b	12.11 ^c
A1T2	3.66	7.58	10.53	12.51 ^{ab}	16.46 ^{abc}
A1T3	4.79	7.31	9.03	12.81 ^{ab}	13.61 ^{bc}
A1T4	5.22	6.58	9.46	10.29 ^b	14.14 ^{bc}
A1T5	4.34	6.88	9.49	11.71 ^{ab}	15.29 ^{bc}
A1T6	5.22	8.66	11.83	13.10 ^{ab}	19.14 ^{ab}
CV (%)	18.75	14.81	11.61	16.98	14.92
F-prob (A)	0.4508	0.4370	0.8617	0.1890	0.0660
F-prob (B)	0.1012	0.0121	0.0003	0.0006	0.0000
F-prob (A x B)	0.4203	0.3743	0.4417	0.0155	0.0508
Means within factor in each column followed by a common/without letter are not significantly different from each other at 5% level of significance using Tukey's Honestly Significant Difference (HSD) Test					

But in weeks 4 and 5, the application of T6 alone was significantly the highest in shoot length that has a height 15.18 cm and 20.70 respectively. [58] concluded that organic fertilizers cannot simply replace inorganic fertilizers in hydroponic solutions. In the study, Hoagland's solution remained a far more complete nutrient solution. Overall, organic hydroponics continues to be widely investigated due to the promising results observed when using purely organic nutrient solutions or in combination with chemical additives, as noted by [58].

In contrast, organic nutrient solutions frequently result in reduced vegetative growth. Research has shown that lettuce grown with organic-based nutrient solutions often exhibits fewer leaves, smaller leaf areas, and lower fresh biomass compared to those grown with inorganic fertilizers [2] [3] [6]. On the other hand, there were no significant difference to the length of shoots in both aerated and non-aerated hydroponic system.

The interaction of organic solutions to either aerated or non-aerated hydroponic system did not show any significant difference to the shoot length of lettuce at weeks 1 to 3. Significant difference was shown only at week 4 and 5. As observed, the application of SNAP solution in non-aerated hydroponics (A0T6) showed the highest shoot length of 17.27 cm. There were treatments that was comparable however to A0T6. These treatments were, from longest to shortest in rank, aerated SNAP solution (A1T6), Fermented Fruit Juice (A1T3), Indigenous Microorganisms (A1T2), non-aerated Pure water (A0T0), and aerated Fish Amino Acid (A1T5).

The other treatments were also showing comparable results to the aforementioned treatments. Then at week 5, performing treatments that contributed to the shoot length of lettuce were A0T6, A1T6, and A1T2 with a length of 22.27 cm, 19.14cm and 16.46 cm respectively. This indicates that applying Liquid Organic Fertilizer

(LOF) with one week of aeration could replace the role of A and B mix of SNAP solution, but longer periods of aeration could decrease the nutritional content of LOF [44].

Root and Shoot Weight Response of Lettuce

Table 4 shows the weight of roots and shoots of lettuce as well as the root to shoot and shoot to root ratio applied with different nutrient solutions under aerated and non-aerated hydroponic system. There was a significant difference in their weight performance under aerated and non-aerated hydroponic where A1 showed better root and shoot weight with an average of 1.33 g and 9 g and no significant difference was shown in terms of root to shoot and shoot to root ratio of lettuce. Oxygen levels play an important role in plant growth, especially in soilless systems a sufficient amount of oxygen needs to be supplied to the root zone to prevent oxygen depletion [17]. The growth and development of lettuce as to the root to shoot and shoot to root ratio on the other hand did not show any significant difference in the aerated and non-aerated hydroponic system.

Table 4. Root and shoot weight response of lettuce plants to different organic solutions under aerated and non-aerated hydroponic system 280

Treatment	Root Weight (g)	Shoot Weight (g)	Root to Shoot Ratio	Shoot to Root Ratio
Factor A				
A0 – Non-Aerated	0.81 ^b	5.81 ^b	0.56	1.84
A1 - Aerated	1.33 ^a	9.00 ^a	0.54	2.04
Factor B				
T0 – Pure Water	1.17	5.00 ^b	0.55 ^a	1.75 ^b
T1 – Probiotics	1.17	6.00 ^b	0.62 ^a	1.57 ^b
T2 – Indigenous Microorganism	1.17	5.67 ^b	0.69 ^a	1.57 ^b
T3 – Fermented Fruit Juice	0.67	4.50 ^b	0.58 ^a	1.90 ^b
T4 – Vermitea	0.83	4.50 ^b	0.53 ^{ab}	1.47 ^b
T5 – Fish Amino Acid	1.17	6.00 ^b	0.63 ^a	1.73 ^b
T6 – SNAP Solution	1.33	20.17 ^a	0.26 ^b	3.58 ^a
A X B				
A0T0	1.00	5.33	7.03	2.53
A0T1	1.00	4.67	6.60	1.63
A0T2	0.67	2.33	6.17	2.17
A0T3	0.33	2.67	6.40	2.67
A0T4	0.67	4.33	6.63	2.73
A0T5	1.00	2.33	6.33	3.77
A0T6	1.00	19.00	10.30	3.13
A1T0	1.33	4.67	6.67	0.80
A1T1	1.33	7.33	7.43	2.63

A1T2	1.67	9.00	7.53	1.70
A1T3	1.00	6.33	7.60	1.63
A1T4	1.00	4.67	6.83	1.83
A1T5	1.33	9.67	7.37	1.00
A1T6	1.67	21.33	8.87	2.27
CV (%)	47.09	63.36	28.11	26.00
F-prob (A)	0.0024	0.0366	0.6296	0.2097
F-prob (B)	0.3015	0.0001	0.0017	0.0000
F-prob (A x B)	0.8687	0.7217	0.9115	0.0854
Means within factor in each column followed by a common/without letter are not significantly different from each other at 5% level of significance using Tukey's Honestly Significant Difference (HSD) Test				

In terms of the application of different nutrient solutions, weight of roots of lettuce did not show any significant difference while significant difference was shown among treatments in the weight of shoots of lettuce where SNAP solution (T6) application was significantly the heaviest with a weight of 20.17 g compared to the organic solutions.

However, root to shoot ratio of lettuce showed that the organic solutions have heavier roots than its shoot where T6 was comparably the lowest compared to the organic solutions. It was however comparable to Vermitea (T4). The shoot to root ratio on the other hand showed SNAP solution (T6) to have heavier shoots than roots with an average shoot to root ratio of 3.58 g. Organic solutions are not as accessible as chemical solutions for crop production in hydroponics, and when they are, they are often a mixture of organic compounds that are only optimized for N, P and K [62 [55].

Moreover, organic fertilizer in hydroponic methods can often be phytotoxic (inhibiting growth) and provoke many challenges, so a greater understanding into its use would be ground-breaking for a sustainable future [19] [20] [30]; as reviewed by [58]. [60] [51] [54] concluded that using commercially available nutrient solutions affects the growth and yield of lettuce in a hydroponic production system. However, its potential used should be further tested for verification under different growing seasons to elicit substantial conclusions for it was shown Study Limitations. The experiment was conducted in one greenhouse location and covered one lettuce cultivar and one growing period. Although the design included three replications, the plants within each box were not independent experimental units. The available records also lack complete nutrient recipes, dilution rates, nutrient analyses, direct dissolved oxygen measurements, environmental readings, and full ANOVA output. The results should therefore be interpreted within the conditions of this experiment. on its root to shoot ratio that there is more bulk of roots in the application of these organic nutrients compared to the commercial SNAP solution.

Meanwhile, the interaction between different nutrient solutions and aerated or non-aerated hydroponic systems did not significantly influence the root and shoot weights of hydroponically grown lettuce, including the root-to-shoot and shoot-to-root ratios. This suggests that although aeration and nutrient composition may affect some growth parameters, their combined effects on biomass partitioning were not sufficient to produce statistically significant differences under the conditions of the study. [25] [38] observed that aeration affected lettuce growth performance; however, responses varied depending on the measured parameter, indicating that some biomass traits may not differ significantly among treatments.



CONCLUSION

The study concludes that both aeration and nutrient solution type significantly influence the growth performance of lettuce (*Lactuca sativa* L. var. Green Rapid) in hydroponic systems. Aeration enhanced plant height, leaf number, and biomass accumulation, particularly during later growth stages, confirming the importance of dissolved oxygen in root-zone development and nutrient uptake.

Among the nutrient solutions, SNAP solution consistently produced superior growth performance in terms of plant height, leaf production, and shoot biomass compared to organic nutrient solutions. Although organic formulations such as IMO, FAA, FFJ, Vermitea, and probiotics supported plant growth, their effects were generally lower than SNAP solution.

Furthermore, significant interaction effects indicate that combining aeration with SNAP solution maximizes lettuce growth, suggesting a synergistic relationship between oxygen availability and complete nutrient supply. However, biomass partitioning (root-to-shoot ratio) was not significantly affected by treatments, indicating stability in assimilate distribution regardless of nutrient source and aeration condition.

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COMPETING INTERESTS

The author declares no conflicts of interest, as the funding agency did not influence the study's design, methodology, data analysis, or conclusions.

AUTHORS' CONTRIBUTIONS

A.J.M.D. was responsible for conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, project administration, and funding acquisition. The author has read and approved the final version of the manuscript. P.P.R., as the adviser, provided supervision, guidance in conceptualization and methodology, critical review of the manuscript, and approval of the final version for submission and publication. The adviser ensured the scientific rigor, clarity, and compliance with research standards throughout the study.

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