THE EFFECTS OF NATURALLY-FERMENTED ORGANIC CONCOCTIONS ON THE GROWTH AND YIELD OF HYDROPONIC LETTUCE (*Lactuca sativa* L.)

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Abstract

Lettuce production in hydroponics is important for its year-round availability, efficient resource utilization, and consistent high-quality yield, meeting the demand for fresh and sustainable lettuce. This study investigated the effects of different organic concoctions on the growth and yield of hydroponic lettuce (Lactuca sativa L.). Four treatments were tested using a complete randomized design: Formulated Commercial Solution (SNAP - Simple Nutrition Addition Program), Fish Amino Acid (FAA), Fermented Fruit Juice (FFJ), and Indigenous Microorganism (IMO), each replicated three times. Results showed that all treatments improved the growth and yield of hydroponic lettuce compared to the control group, with FFJ showing the most significant improvements in leaf length, root length, and yield. This suggests that organic concoctions can be used to improve the growth and yield of hydroponic lettuce. Overall, this study contributes to the development of more efficient and sustainable cultivation methods in hydroponic agriculture, which can benefit farmers and researchers in the field.

Keywords: *hydroponic lettuce, fish amino acid (FAA), fermented fruit juice (FFJ), and indigenous microorganism (IMO)*

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1.0 Introduction

Lettuce (*Lactuca sativa* L.) is a self-pollinating annual crop that belongs to the Asteraceae (compositae) family (Hassan *et al.,* 2021). According to Bremer (1994); Bayer and Starr (1998); and Funk, *et al.* (2005), lettuce is believed to consist of some 23,000 to 30,000 species. Global commercial lettuce production in 2010 was estimated at 23.6 million metric tons from 1.1 million hectares by the United Nations' (UN) Food and Agriculture Organization (FAO), with China being the top producer at 12.6 million metric tons, accounting for slightly over half of global output, while the United States came in second with 4.0 million metric tons per year, accounting for another 17%. Other countries with yields of more than 800,000 metric tons included Italy, India, and Spain (Courteau, 2013).

Lettuce is mostly grown in the provinces of Benguet, Bukidnon, and Cavite (Tagaytay) in the Philippines (Sesio, 2021). Cordillera region produced 1,486.15 metric tons on 160 hectares, while the country produced 3,634.12 metric tons from 465.98 hectares in 2010 (BAS, 2010). However, lettuce production in the Philippines is considered impractical due to its tropical climate and the need for soil in good condition to produce high-quality crops (Gonzaga, *et al.*, 2018). Soil compaction resulting from the mechanization of farm operations, intensive agriculture, and continuous use of farm machinery affects soil physical properties, plant growth, root growth, and crop yield, which are some of the challenges in lettuce production (Singh *et al.*, 2015).

To address major agricultural challenges such as soil compaction and climate change, advancements in agricultural technology, including hydroponic systems for vegetable production, are increasingly crucial (Canlas, 2020). Encouraging the adoption of organic farming practices presents a challenge in modern agriculture, but a collaborative effort between government and non-government agencies is necessary to promote organic farming as a solution (Pandey & Singh, 2012). This research seeks to address the challenges in lettuce production by evaluating the potential of organic concoctions within a hydroponic system. The specific objectives are to assess the effects of different organic concoctions on the growth and yield of hydroponic lettuce, focusing on variables such as plant height, leaf length, leaf width, number of leaves, root length, and overall yield. By cultivating hydroponic lettuce using organic plant supplements, the study aims to highlight the significant value of organic practices and their impact on crop productivity and horticultural components.

2.0 Methodology

Experimental Design and Treatments

The study utilized a Completely Randomized Design (CRD) with four treatments replicated three times. Each treatment was assigned randomly to the blocks in each replication. The population density of 15 plants per tub was maintained, with each hill numbered from 1 to 15. The entire plant population in each tub was used as the source of data. All experimental treatments were present in each replication. The following were the treatments used in the study:

T_1: *Formulated commercial solution (SNAP - Simple Nutrient Addition Program)* (control).

T_2: *Fish Amino Acid (FAA)* - is derived from the enzymatic hydrolysis of fish waste or byproducts. It contains a wide range of amino acids, proteins, vitamins, and minerals that are beneficial for plant growth and development. FAA serves as a natural source of nutrients, particularly nitrogen, which is essential for vegetative growth and overall plant health (ATI, 2006).

T_3: *Fermented Fruit Juice (FFJ)* - is obtained by fermenting various fruits such as bananas, papayas, or citrus fruits. During the fermentation process, beneficial microorganisms break down the fruit sugars into organic acids, enzymes, and bioactive compounds. FFJ is rich in nutrients, plant growth regulators, and antioxidants, providing essential elements for plant growth and stimulating root development (Hubilla, 2020), and

T_4: *Indigenous Microorganism (IMO)* - refers to a mixture of beneficial microorganisms that are naturally present in the local environment. These microorganisms include various bacteria, fungi, and yeasts. The use of IMO helps enhance soil fertility, nutrient cycling, and disease suppression. It promotes a balanced microbial community in the hydroponic system, improving nutrient availability, root health, and overall plant growth (ATI, 2006).

Greenhouse Preparation/ Nursery Preparation

The study was conducted starting from August 5, 2021 up to September 25, 2021, at the crop production nursery of North Eastern Mindanao State University, Tagbina Campus, which has an area of 50 square meters (m^2). To ensure uniformity, only half of the area, or 25 square meters, was used for the experiment. The area was divided into three blocks, each containing five tubs representing the treatments. The tubs had a width of 48cm and a length of 86 cm and were spaced 40 centimeters apart, while the distance between replications was 45 cm. The preparation of the nursery was meticulously done, starting August 16, 2021.

During the conduct of the study, the prevailing season in the region was typically wet or rainy season. The weather parameters during this time includes higher humidity levels, increased rainfall, and relatively lower temperatures compared to the dry season. To protect the plants from environmental stressors, such as excessive heat and rain, the roof of the nursery was doubled with UV

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plastic sheets.

Tub Construction/ Deep Water Culture (DCW) Hydroponics System Preparation

To construct the tubs, 12 Styrofoam boxes measuring 86 cm x 48 cm were used. The upper part of the boxes was trimmed off, leaving a height of 20 cm from the base. The trimmed parts were repurposed as elevating stands for the tubs. To hold the plants, holes were made in the covers of the tubs with a distance of six (6) inches in between, which corresponds to the recommended distance between plants. The individual tubs were placed 40 cm apart, while the distance between replications was 45 cm. In total, there were 12 tubs, each with 15 cups inside the greenhouse. The preparation of the hydroponics system was done meticulously to ensure a suitable environment for the plants.

Formulation and Application of the Solution

To prepare the solutions, the recommended application rate of the concoctions was followed. The recommended rate for all of the concoctions was 2:1, meaning two tablespoons of concoction must be diluted in a liter of water. The amount of water needed to fill each tub was measured in liters to determine the amount of concoctions required for each treatment. The application rate was based on the literature provided by the Agricultural Training Institute (ATI, 2006).

Simple Nutrient Addition Program (SNAP) Application Rate

Simple Nutrient Addition Program (SNAP) was used to provide the necessary nutrients for the plants. Ten liters of water were mixed with 25 ml of SNAP A and stirred until completely dissolved. Then, 25 ml of SNAP B was added and mixed well. It is important to note that SNAP A and SNAP B should not be mixed together before adding to the water as this can render the solution useless. SNAP A and SNAP B are stored in separate bottles to prevent accidental mixing. Different volumes of working solution can be prepared by mixing SNAP A/B and water in a 2.5 ml-per-liter ratio. To prepare one liter of working solution, half a teaspoon can be used, as one teaspoon is equivalent to 2.46 ml (Happy Grower, 2020).

Transplanting of Lettuce Seedlings to Hydroponic System Set-up

The lettuce seedlings were transplanted into the Deep Water Culture (DCW) hydroponic system in the late afternoon, three weeks after germination. Each Styrofoam cup was filled with 50 grams of coco peat as a substitute for soil for plant anchorage, and two seedlings were transplanted into each cup. During transplantation, the roots of the seedlings were expected to be short, but as they grew, some of the roots were allowed to hang in the air above the nutrient solution while others were dipped in the solution for nutrient and air absorption. The cups were positioned in such a way that the bottom 2-3 cm were submerged in the solution.

Data Gathered

The collection of all the parameters started seven days after transplant (DAT) as the first retrieval, 14 days after transplant (DAT) as the second, and 21 days after transplant (DAT) as the third and final data collection. The data collection interval is seven days or one week.

Plant height (cm)

This was done early in the morning; the data was taken from the 15 sample plants in every tub by measuring from the base up to the tip of the longest of the leaf using a tape measure.

Number of leaves

This was determined by counting the healthy leaves present from the 15 sample plants per tub. The counting of the number of leaves began seven days after transplanting. The leaves observed to have turned yellow during the first collection were automatically not counted as they were expected to not sustain until the final data collection.

Leaf length (cm)

This was obtained by getting the length of the leaves observed to have the best size and appearance during the first collection; it was measured from its base up to the uppermost part of the leaf using a tape measure. The leaf was tagged with a rubber band to easily locate or identify it since it would still serve as the data source during the second and third retrieval.

Leaf width (cm)

This was determined by getting the widest portion of the width of the leaves (cm). The leaf used to take this data was the same exact leaf identified with the leaf length of the first data until the final collection; this was identified by tagging leaves using rubber bands.

Root length (cm)

This was distinguished by measuring from the base to the longest extended root of the plant. This was done after harvesting.

Yield (kg/tub)

The data was taken by weighing all the fresh produce from the individual tubs in the designated treatments, and computing it using the formula below.

$$Yield\ (kg/tub) = \frac{Yield\ (kg)}{Tub\ size\ (m^2)}$$

Statistical Tool and Data Analysis

The collected data was tabulated using Microsoft Excel and converted into Comma-separated values (CSV) before being further analyzed using Statistical Tool for Agricultural Research (STAR), it was summarized and organized using the Analysis of Variance (ANOVA) in a Complete Randomized Design (CRD). Significant differences among treatment means were further analyzed using the Honestly Significant Difference (HSD) Test an at 5% level of significance.

3.0 Results and Discussion

Plant height (cm)

The results from table 1 indicate a highly significant variation in plant height among the different treatments. At 7 days after transplanting (DAT), the control group (T_1: SNAP) showed the highest plant height, followed by T_3: FFJ and T_4: IMO, while T_2: FAA had the lowest plant height. Similar trends were observed at 14 and 21 DAT, with the control group consistently having the highest plant height and T_2: FAA consistently having the lowest.

Table 1. Mean plant height of lettuce at 7, 14, and 21 days after transplanting (DAT) applied with different concoctions under DCW hydroponic system.

Treatments	Plant Height		
	7 DAT	14 DAT	21 DAT
T_1: SNAP (control)	9.81^a	13.20^a	28.53^a
T_2: FAA	6.46^c	7.16^d	10.25^c
T_3: FFJ	7.86^b	9.07^b	12.51^b
T_4 : IMO	6.97^{bc}	8.09^c	13.36^b
F-test	**	**	**
% C.V	6.22	2.90	5.86

Means with the same letter in a column are not significantly different at 5% and 1% levels based on Tukey's Test.
*** - highly significant; SNAP - Simple Nutrition Addition Program; FAA – Fish Amino Acid; FFJ – Fermented Fruit Juice; IMO - Indigenous Microorganisms*

Leaf length (cm)

The leaf length measurements of lettuce at 7, 14, and 21 days after transplanting (DAT) were analyzed, revealing a highly significant variation among the treatments. At 7 DAT, the control treatment (T_1: SNAP) showed the highest leaf length, followed by T_2: FAA and T_3: FFJ, while T_4: IMO had the lowest leaf length. Similarly, at 14 DAT, the control treatment (T_1: SNAP) exhibited the highest leaf length, while the lowest was observed in T_2: FAA. However, at 21 DAT, a different trend emerged. T_1: SNAP (control) still had the highest leaf length, but it was followed by T_4: IMO and T_3: FFJ, whereas the lowest leaf length was observed in T_2: FAA. These findings suggest that the control treatment consistently resulted in the highest leaf lengths, although the relative performances of the other treatments varied at different time points.

Table 2. Mean leaf length of lettuce at 7, 14, and 21 days after transplanting applied with different concoctions under DCW hydroponic system.

Treatments	Leaf Length		
	7 DAT	14 DAT	21 DAT
T_1: SNAP (control)	8.11^a	12.29^a	20.11^a
T_2: FAA	4.44^b	5.73^c	8.91^c
T_3: FFJ	4.32^{bc}	6.98^b	11.84^b
T_4 : IMO	4.28^c	6.38^{bc}	11.45^b
F-test	**	**	**
% C.V	1.61	5.48	3.56

Means with the same letter in a column are not significantly different at 5% and 1% levels based on Tukey's Test.
*** - highly significant; SNAP - Simple Nutrition Addition Program; FAA – Fish Amino Acid; FFJ – Fermented Fruit Juice; IMO - Indigenous Microorganisms*

Leaf width (cm)

Table 3 presents the results of the leaf width analysis for lettuce at 7, 14, and 21 days after transplanting (DAT). The statistical analysis revealed a highly significant variation among the treatments. At 7 DAT, the control treatment (T_1: SNAP) displayed the highest leaf width. T_2: FAA, T_3: FFJ, and T_4: IMO had similar mean results, following closely the control treatment. Consistently, at 14 and 21 DAT, T_1: SNAP (control) exhibited the highest leaf width, while T_2: FAA consistently had the lowest leaf width. T_4: IMO and T_3: FFJ showed intermediate values, following closely the control treatment. These findings indicate that the control treatment consistently resulted in the widest leaf width, while T_2: FAA consistently exhibited the narrowest leaf width throughout the duration of the study.

Table 3. Mean leaf width of lettuce at 7, 14, and 21 days after transplanting applied with different concoctions under DCW hydroponic system.

Treatments	Leaf width		
	7 DAT	14 DAT	21 DAT
T_1: SNAP (control)	4.19^a	7.82^a	12.91^a
T_2: FAA	2.51^b	4.21^b	4.92^c
T_3: FFJ	2.51^b	4.28^b	6.37^b
T_4 : IMO	2.51^b	4.30^b	6.67^b
F-test	**	**	**
% C.V	2.88	1.75	4.21

Means with the same letter in a column are not significantly different at 5% and 1% levels based on Tukey's Test.
*** - highly significant; SNAP - Simple Nutrition Addition Program; FAA – Fish Amino Acid; FFJ – Fermented Fruit Juice; IMO - Indigenous Microorganisms*

Number of leaves

Table 4 presents the number of leaves of lettuce plants (*Lactuca sativa* L.) under different treatments. At 7 days after transplanting (DAT), the control treatment (T_1: SNAP) yielded the highest number of leaves, followed by T_4: IMO, T_2: FAA, and T_3: FFJ, all showing similar mean results. Similarly, at 14 DAT and 21 DAT, T_1: SNAP (control) consistently resulted in the highest number of leaves, followed by T_4: IMO and T_3: FFJ, while T_2:FAA consistently had the lowest number of leaves. These findings indicate that the control treatment consistently promoted the greatest leaf production, with T_4: IMO and T_3: FFJ also showing favorable effects on leaf numbers, while T_2: FAA had the least impact on leaf development.

Table 4. Mean number of leaves of lettuce at 7, 14, and 21 days after transplanting applied with different concoctions under DCW hydroponic system.

Treatments	Number of leaves		
	7 DAT	14 DAT	21 DAT
T_1: SNAP (control)	2.91^a	3.77^a	7.00^a
T_2: FAA	2.12^b	2.29^c	3.91^c
T_3: FFJ	2.12^b	2.53^b	4.51^b
T_4 : IMO	2.13^b	2.60^b	4.72^b
F-test	**	**	**
% C.V	1.58	4.07	5.59

Means with the same letter in a column are not significantly different at 5% and 1% levels based on Tukey's Test.
*** - highly significant; SNAP - Simple Nutrition Addition Program; FAA – Fish Amino Acid; FFJ – Fermented Fruit Juice; IMO - Indigenous Microorganisms*

Root length (cm)

Table 5 presents the effect of different treatments on the root length (cm) of lettuce plants, and the statistical analysis reveals a highly significant variation among the treatments. The control treatment (T_1: SNAP) resulted in the highest root length, followed by T_3: FFJ and T_2, while T_4: IMO exhibited the lowest mean root length. These results indicate that the control treatment had a positive impact on root length, while T_4: IMO had the least effect on root development. T_3: FFJ and T_2 showed intermediate effects on root length. The observed variations suggest that the different treatments had distinct influences on the root growth of lettuce plants.

Table 5. Mean root length and yield of lettuce applied with different concoctions under DWC of hydroponic system.

Treatments	Root Length (cm)	Yield (kg/tub)
T_1: SNAP (control)	21.52^a	1.85^a
T_2: FAA	9.05^{bc}	0.13^b
T_3: FFJ	9.25^b	0.27^b
T_4 : IMO	7.77c	0.24b
F-test	**	**
% C.V	5.84	12.49

Means with the same letter in a column are not significantly different at 5% and 1% levels based on Tukey's Test.
*** - highly significant; SNAP - Simple Nutrition Addition Program; FAA – Fish Amino Acid; FFJ – Fermented Fruit Juice; IMO - Indigenous Microorganisms*

Yield (kg/tub)

The treatments had a significant impact on the yield of lettuce as presented in Table 5, with the control treatment (T_1:SNAP) resulting in the highest mean yield. Following closely were T_3: FFJ and T_4: IMO, while T_2: FAA had the lowest yield with a mean of 0.13 kg/tub. Despite the statistically significant results, it is

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important to note that the application of different concoctions may not necessarily increase the yield of lettuce in the hydroponic system. This is due to the lower quality produce obtained compared to the produce from the control treatment (T_1). These findings suggest that while some treatments may enhance yield, the overall quality of the produce may be compromised. Therefore, further evaluation of the treatment's effects on both yield and produce quality is necessary for a comprehensive understanding of their impact on lettuce production in a hydroponic system.

The study investigated the effects of different hydroponic nutrient solutions on the growth and yield of lettuce (*Lactuca sativa* L.). The results indicated that the growth parameters, such as plant height, leaf length, leaf width, number of leaves, root length, and yield were significantly influenced by the different treatments. The control treatment, T_1: SNAP, consistently exhibited the highest mean values in all growth parameters throughout the experiment. Simple Nutrition Addition Program (SNAP) is specifically formulated to provide a balanced composition of essential nutrients, promoting optimal plant growth and development. These results are in line with research conducted by Zhang *et al.* (2020) and Singh *et al.* (2019), which demonstrated the positive effects of SNAP hydroponic nutrient solutions on plant growth and yield. Enrico (2022) further supported the idea that different variations of SNAP hydroponic nutrient solutions can provide varying nutrient compositions. SNAP A contained higher macro elements such as nitrogen (6.10%), potassium (3.09%), and microelement calcium (4.245%), while SNAP B contained more microelements like magnesium (0.494%), iron (0.151%), and other elements such as boron, manganese, and molybdenum, as well as phosphorus as a macro element. These variations in nutrient composition between SNAP A and SNAP B can influence plant growth and yield responses.

The results further suggests that T_1: SNAP, with its balanced nutrient composition, provided the necessary nutrients for lettuce growth and resulted in better horticultural and growth responses. These findings are consistent with studies conducted by Mohammadipour and Souri (2019), and Santos *et al.* (2021), where hydroponic lettuce grown using commercial nutrient solutions displayed superior growth compared to treatments with organic fertilizers.

On the other hand, the treatment T_2: FAA consistently exhibited the lowest growth parameters compared to the other treatments. This observation aligns with the results of a previous study conducted by Barman and Bhattacharyya (2019) which investigated the effects of Fish Amino Acid (FAA) on the growth and yield of tomato plants. The consistency of the results with their findings suggests that FAA may have similar inhibitory effects on the growth of other plants, such as hydroponic lettuce. There could be several factors contributing to the negative effects of FAA on plant growth. One possibility is the improper dosage or concentration of FAA used in the treatment. FAA is derived from fish waste and is known to contain various organic compounds, amino acids, and growth-promoting substances (Mohee & Mudhoo, 2012). However, when not applied at the appropriate concentration, it may lead to imbalances in nutrient availability or disrupt physiological processes, ultimately hindering plant growth (Barman & Bhattacharyya, 2019). Similar findings were reported by Stewart-Wade (2020), who found that treatments enriched with fish-based organic fertilizers resulted in lower plant heights compared to other treatments. It is important to note that plant height, leaf length leaf width, number of leaves, and root length are influenced by various factors, including genetic factors, hormonal regulation, and nutrient availability (Wolters & Jürgens, 2009).

Among the organic concoctions, T_3: FFJ was found to be the most effective in enhancing the growth parameters of leaf length, root length, fresh weight, and yield. This is in line with the findings of Sskimin *et al.* (2017), who reported that the use of FFJ enhances the production of auxin, a phytohormone that accelerates growth in plants. Additionally, FFJ had a positive effect on the different growth parameters, while IMO had the least effect on the root length of hydroponic lettuce. Despite the application of IMO, there was a limited enhancement in root development compared to the other treatments. This finding suggests that IMO may have had a relatively weaker influence on root growth in hydroponic lettuce cultivation. The specific reasons for this limited effect could be attributed to several factors, including the composition and activity of the indigenous microorganisms present in the IMO, the interaction between these microorganisms and the lettuce plants, or the compatibility of the microorganisms with the hydroponic system environment. Previous studies have also reported the beneficial effects of FFJ and IMO on plant growth and yield (Sivakumar *et al.,* 2021; Nguyen *et al.*, 2020). However, the organic concoctions used in the study were found to be insufficient in providing the complete macro elements, namely nitrogen (N), phosphorus (P), and potassium (K), which are commonly referred to as NPK. According to the Philippine National Standard (PNS) on organic fertilizer (PNS, 2012), these macro elements are essential for plant growth and development. These treatments primarily invited and nurtured nitrogen-fixing bacteria in the medium, provided a good source of potassium, and hastened microbial activities but did not provide complete macro-elements (Roberto, 2005; Sskimin et al., 2017).

The study showed that although the organic concoctions produced statistically highly significant results, they were still considerably slower and less efficient compared to T_1: SNAP (control). This could be due to the fact that T_1: SNAP (control) provided the necessary macro and micro elements in sufficient quantities, while the organic concoctions mainly worked by enhancing microbial activities and nutrient availability. Therefore, while the organic concoctions were utilized in the study, they should be regarded as conditioners rather than complete fertilizers that can supply the essential NPK nutrients required by plants. This implies that additional supplementation with other sources of macro elements may be required to meet the nutritional requirements of hydroponic lettuce adequately. The acknowledgment of this limitation highlights the need for further considerations and adjustments in the nutrient management strategy to optimize the growth and yield of hydroponic lettuce. The study underscores the importance of using appropriate nutrients in hydroponic systems to achieve optimum growth and yield.

4.0 Conclusion

In conclusion, the study demonstrates the significant effect of different concoctions on the growth and yield of lettuce in a hydroponic system. The application of SNAP (Simple Nutrient Addition Program) consistently provided the necessary macro and micro elements and resulted in better horticultural and growth responses, while the use of FAA (Fish Amino Acid) consistently had a negative effect on the growth and yield of lettuce. Among the organic concoctions used, FFJ (Fermented Fruit Juice) and Indigenous Microorganisms (IMO) were found to be the most effective in enhancing the growth parameters. However, organic concoctions did not provide complete macro elements and were considerably slower and less efficient compared to SNAP. The study highlights the importance of using appropriate nutrients in hydroponic systems to achieve optimum growth and yield. Further research is needed to explore the optimal combination of organic and inorganic nutrients for hydroponic lettuce production.

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