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Performance of lettuce (*Lactuca sativa* L.) under hydroponic culture using formulated organic nutrients (FON)

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Abstract The incorporation of organic solutions is gaining attention due to their ability to promote plant growth and support more sustainable agricultural practices. In this study, the different nutrient solutions used affected the growth and yield of lettuce. Lettuce grown on SNAP solution (T1) had the tallest plants, longest roots, the greatest number of leaves produced, the widest and longest leaves, and the heaviest overall yield. However, this was found insignificant compared to the plants grown on the formulated organic nutrient solution, FON with chicken dung and molasses (T2). Notably, T2 had similar responses to T4 (FON with chicken dung and without molasses) and T3 (FON with cow manure and without molasses) in terms of plant height, number of leaves produced, width of leaves, length of roots, biomass, and non-marketable part. Conversely, lettuce grown on T5 (FON with hog manure and without molasses) exhibited the least number of leaves produced, narrowest leaves, shortest root length, and lightest overall yield, similar to T3 and T4 solutions. Among the nutrient solutions used, T2 generated the highest net profit, followed by T3, T1, and T5, while T4 had the lowest net income. It indicated that T2 could be a viable alternative to conventional synthetic solutions for hydroponic lettuce production as it performs similarly under favorable conditions. Additionally, varying nutrient solutions had a noticeable impact on both the percentage of light absorption and the weight of the sediment in the solution. Lighter solutions, such as T1 (colorless), T5 (baby yellow), and T2 (gold ochre), exhibited higher percentages of light absorption. In contrast, the darker solutions, including T3 (chocolate and chrome orange) and T4 (brown and red wood), were found to absorb significantly less light. Overall, these findings underscored the potential of organic nutrient solutions in enhancing lettuce growth and profitability.

Keywords: Formulated Nutrient Solution, Hydroponic Culture, Lettuce, Organic

Introduction

Lettuce (*Lactuca sativa* L.) is a widely consumed leafy vegetable, recognized for its nutritional value and adaptability in various dishes. Its market potential is growing, driven by the rising demand for salad vegetables (Gonzaga *et al.*, 2018). The demand for high yields and high-quality produce through a

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soilless cultivation method, which can be adapted to different environmental conditions, has fueled interest in this approach as a potential solution to the global food security challenge (Sambo *et al*., 2019).

Hydroponics is a modern agricultural practice where plants are grown in a water and nutrient solution, with or without a soilless substrate for physical support (Niu and Masabni, 2022; Woodard, 2024; Saldinger *et al*., 2023; Khan *et al*., 2018). It is an alternative agricultural production method that emphasizes climate adaptability, efficient use of resources, and the production of disease-free crops (Rajendran *et al*., 2024; Kannan *et al*., 2022). This technique enables precise management of nutrient delivery, resulting in faster growth rates compared to conventional soil-based methods (Huber, 2024). Moreover, it provides various benefits, such as the potential for greater yields and higher-quality produce, better nutrient control, more efficient water usage, reduced toxic chemical exposure, a smaller ecological footprint, and the ability to cultivate plants, particularly in areas with poor soil conditions or limited land availability (Rajendran *et al*., 2024; Banerjee *et al*., 2022; Lee and Lee, 2015).

Park and Williams (2024) and Kumari *et al.* (2018) noted that ongoing challenges in food production, such as climate change, reduced freshwater resources, shrinking arable land, and unequal access to fresh local produce in urban areas, have driven the increased reliance on hydroponics.

However, commercially available synthetic inorganic fertilizers have been extensively utilized to formulate nutrient solutions in hydroponic crop production (Solis and Magaret, 2022; Phibunwatthanawong and Riddech, 2019; Khodijah *et al.*, 2021). While these nutrient solutions can offer precise delivery of essential nutrients, resulting in optimal plant growth and, in some cases, increased yields, they are also associated with environmental challenges. The heavy reliance on chemical fertilizers often leads to nutrient runoff, which can contaminate surrounding ecosystems and contribute to pollution, raising concerns about sustainability and long-term environmental impact (Garg and Balodi, 2014). Furthermore, this typically has higher initial costs due to the reliance on commercially manufactured nutrients (Fathidarehnijeh *et al.*, 2023; Timsina, 2018).

Recently, there has been growing interested in using organic solutions in hydroponics due to their potential to improve plant growth and support sustainable agricultural practices (Muhie, 2022; Gomiero, 2018). This surge in interest is primarily fueled by the rising consumer demand for organic products, which aligns with a broader emphasis on sustainability and environmental responsibility. Organic-based materials are also being explored for their potential as biostimulants, further enhancing plant health and productivity (Park and Williams, 2024). Additionally, the use of hydroponic systems with organic inputs in urban environments offers the opportunity to grow organic, fresh vegetables without the need for synthetic fertilizers and chemicals, particularly in regions where traditional organic farming is not possible (Park and Williams, 2024; Ahmed *et al.*, 2021). Moreover, organic hydroponics is becoming an essential part of developing innovative technologies that integrate food production, water management, energy use, and waste repurposing for nutrient generation, all of which contribute to a more circular and sustainable food system (Park and Williams, 2024).

The integration of organic solutions in hydroponic systems promotes plant health and supports the principles of organic agriculture, which emphasize sustainability, environmental health, and the use of natural inputs (Chowdhury *et al.*, 2024). By using organic substrates, hydroponic systems can reduce the reliance on synthetic inputs, minimize environmental impact, and produce high-quality, organic-certified lettuce (Atkin and Nichols, 2004).

This study explores the performance of lettuce under hydroponic culture using various formulated organic nutrients (FON) by the Capiz State University (CAPSU), compared with a standard synthetic nutrient solution, SNAP. Focusing on the assessment of growth and yield of lettuce, as well as the economic viability of the different nutrient solutions. Additionally, the study aims to evaluate the effects of these solutions on light absorption and sedimentation, which are critical factors influencing the efficiency of hydroponic systems.

Formulated organic nutrients (FON) is a promising alternative to conventional synthetic nutrient solutions in hydroponics. They are derived from organic sources, such as animal manures and plant-based materials, which can provide a more sustainable, cost-saving, and eco-friendly option as a source of hormones and nutrients in agricultural production (Charoenpakdee, 2014).

The continued research and innovation in the use of organic substrates in hydroponics are essential for optimizing lettuce production and promoting sustainable agricultural practices. By investigating the potential of organic nutrient solutions in hydroponics, this research was aimed to contribute to the development of sustainable and cost-effective practices for lettuce production, especially in regions where organic farming is becoming increasingly prioritized.

Materials and method

Experimental area

The study was conducted at the Organic Agriculture Project of Capiz State University (CAPSU), Burias, Mambusao, Capiz, Philippines, in February 2024.

Experimental design

The experiment was laid out using the Completely Randomized Design with three replications to ensure the reliability and validity of the results. The treatments were the different formulated organic nutrients (FON), composed of T1 – SNAP (control), T2 – FON with chicken dung and molasses, T3 – FON with cow manure and without molasses, T4 – FON with chicken dung and without molasses, and T5 – FON with hog manure and without molasses.

Plant and experimental preparations

Deep water culture utilizing tuna boxes and Styrofoam cups was utilized in the hydroponic system. Coco peat was used as an aggregate substrate, providing a stable medium for the plants' roots. Lettuce seedlings were initially raised in the nursery until they produced three (3) leaves, after which they were carefully transplanted in the hydroponic setup.

Organic nutrient solutions were prepared by weighing 1 kilogram each of the Formulated Organic Nutrient (FON) and placing it in a fine mesh net to confine the solid particles. These nutrient bags were then soaked in the 26 liters of tap water in their designated tuna boxes. For the SNAP solution (control), the manufacturer's recommendation was followed. For uniformity, 26 liters of the prepared SNAP solution were placed in the designated tuna boxes. The lettuce plants were harvested 30 days after transplanting, allowing sufficient time for growth and nutrient absorption.

A detailed breakdown of the components for each formulated organic nutrient for a clear outline and comparison of the treatments is shown in Table 1.

Table 1. Different formulated organic nutrient (FON)

Treatment	Components
T1 (control)	SNAP A and B
T2	Chicken dung, molasses, compost, vermicast, effective micro-organism inoculant, garden soil, rice bran, carbonized rice hull, fermented plant juice, fish amino acid, indigenous microorganism, lactic acid, water
T3	Cow manure, garden soil, rice bran, carbonized rice hull, fermented plant juice, fish amino acid, indigenous microorganism, lactic acid, water
T4	Chicken dung, garden soil, rice bran, carbonized rice hull, fermented plant juice, fish amino acid, indigenous microorganism, lactic acid, water
T5	Hog manure, garden soil, rice bran, carbonized rice hull, fermented plant juice, fish amino acid, indigenous microorganism, lactic acid, water

Data collection and statistical analyses

Growth and yield parameters such as plant height, stem diameter, number of leaves, width of leaves, length of leaves, leaf color, length of roots, biomass, weight of marketable and non-marketable parts, pH, volume of the remaining water, weight of sediments, and % light absorption were gathered and analyzed using the STAR software, except for the descriptive data. Differences among treatment means were compared using the Least Significant Difference test (LSD) and Duncan Multiple Range Test (DMRT).

Results

Growth response of lettuce to the different formulated organic nutrient solutions

The different nutrient solutions had significantly affected the growth of lettuce, except for the stem diameter. The lettuce grown on SNAP solution (T1) had the tallest plants, produced the longest roots, had the most numbers of leaves, and had the widest and longest leaves as presented in Figure 1. However, plants grown on the formulated organic nutrient solution, FON with chicken dung and molasses (T2), did not differ statistically from those grown in SNAP solution.

Additionally, among the organic solutions, T2 was found comparable to T4 (FON with chicken dung and without molasses) in terms of plant height and number of leaves produced, and to T3 (FON with cow manure and without molasses) when it comes to width of leaves and length of roots.

On the other hand, lettuce grown on T5 (FON with hog manure and without molasses) had the least number of leaves produced, narrowest leaves, shortest root length, and smallest stems, which was also found similar to T3 and T4 solutions.

Moreover, the color of the leaves was determined using the leaf color palette for lettuce as shown in Figure 2. All of the leaves of lettuce during the first week were similar with the shade B. In the 2nd week, some of the leaf was similar to shade C but a majority of shade B. As the plant grows and the leaf becomes wider, longer, and thicker, most of the leaves were similar to shade C, especially the plants applied with T1 (SNAP) and T2 (FON with chicken dung and molasses).

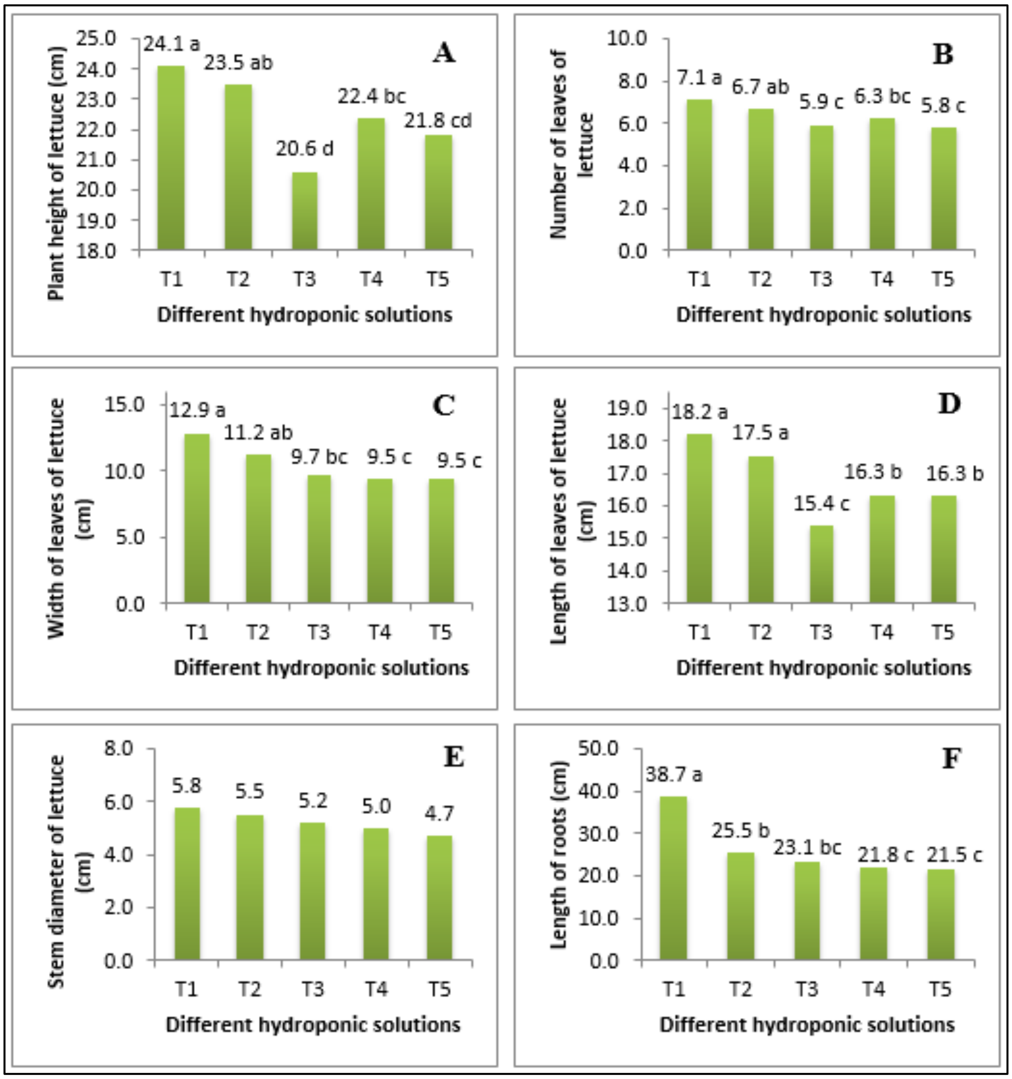

Figure 1. Plant height (A), number of leaves (B), width of leaves (C), length of leaves (D), stem diameter (E), and length of roots (F) of lettuce as affected by the different formulated organic nutrient solutions T1– SNAP (control), T2 – FON with chicken dung and molasses, T3 – FON with cow manure and without molasses, T4 – FON with chicken dung and without molasses, and T5 – FON with hog manure and without molasses

Figure 2. Lettuce color pallet, accessed at https://www.dreamstime.com/backgroundcloseup -curly-lettuce-leaves-colour-palette-complimentary-colour-swatches-lettuce-palette-image246679351

Yield performance of lettuce with the different formulated organic nutrient solutions

Yield parameters such as biomass and weight of marketable and non-marketable parts of lettuce were influenced by the different nutrient solutions. Result showed that the heaviest biomass, marketable and non-marketable part was recorded from the lettuce grown on the T1 (SNAP) solution (Figure 3). However, it was found insignificant compared to the plants grown on the formulated organic nutrient solution, T2 (FON with chicken dung and molasses).

In addition, the use of T2, T3 (FON with cow manure and without molasses), and T4 (FON with chicken dung and without molasses) also had a comparable biomass and non-marketable part. Among the organic nutrient solutions, lettuce grown on T3, T4, and T5 (FON with hog manure and without molasses) exhibited the similar and lightest biomass, marketable and non-marketable parts.

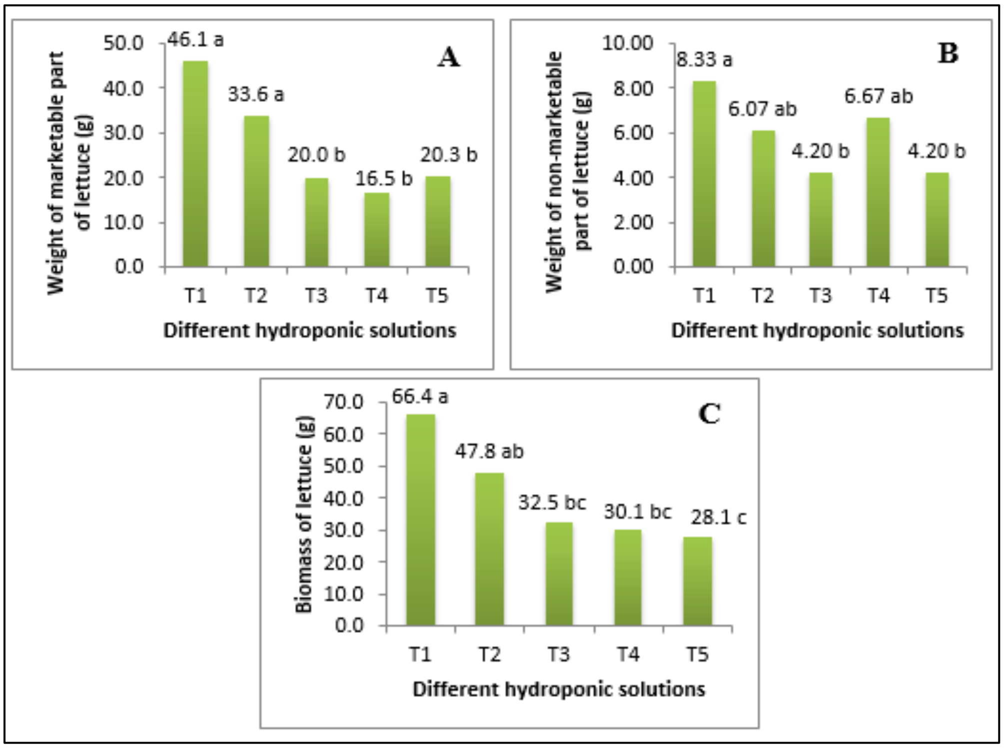

Figure 3. Weight of marketable part (A), weight of non-marketable part (B), and biomass (C) of lettuce as affected by the different formulated organic nutrient solutions T1– SNAP (control), T2 – FON with chicken dung and molasses, T3 – FON with cow manure and without molasses, T4 – FON with chicken dung and without molasses, and T5 – FON with hog manure and without molasses

Furthermore, lettuce planted in the different hydroponic nutrient solutions significantly obtained a 100% survival rate.

Net income over nutrient solutions cost of lettuce applied with the different hydroponic nutrient solutions

Among the hydroponic nutrient solutions used, lettuce applied with T1 (SNAP) obtained the highest gross income amounting to Php 1,313.66, followed by T2 (FON with chicken dung and without molasses), T4 (FON with chicken dung and without molasses), and T3 (FON with cow manure and without molasses) with the amounts of Php 793.80, Php 600.48, and Php 590.40, respectively. The lowest net income was recorded in the lettuce applied with T5 (FON with hog manure and without molasses), amounting to Php 531.00.

However, after deducting the solution cost and other production costs as reflected in Table 2, the highest net profit was generated from T2 (Php 542.00), followed by T3 (Php 355.48). T1 generated a net income of Php 333.00, T5 has a net income of Php 286.00, and the lowest net income was generated from T4 (Php 245.00).

Table 2. Income over solution cost of organically produced lettuce under hydroponic cultivation

PARTICULARS	TREATMENTS				
	T1	T2	T3	T4	T5
Cost of Seedlings (P) [a]	180.00	180.00	180.00	180.00	180.00
Amount of substrate	200 ml	3.00 kg	3.00 kg	3.00 kg	3.00 kg
Cost of substrate (P)[b]	800.00	36.00	30.00	30.00	30.00
Nylon Net (P) [c]	0	35.00	35.00	35.00	35.00
Total cost of production (P)	980.00	251.00	245.00	245.00	245.00
Gross Income	1,313.66	793.80	600.48	590.40	531.00
Net income	**333.00**	**542.00**	**355.48**	**245.00**	**286.00**

a = seedling cost at P 2.00/seedling
b = for SNAP cost is P 4.00/ml; for T2 P 12.00/kg; T3, T4, and T5 P 10.00/kg
c = nylon net cost is P35.00/m

Formulated nutrient solution (FON)

The different hydroponic substrates was not influenced the pH of the nutrient solutions; however, based on the weekly analysis, the pH of the T1 (SNAP) and T2 (FON with chicken dung and molasses) increases every week, while for the T3 (FON with cow manure and without molasses), T4 (FON with chicken dung and without molasses), and T5 (FON with hog manure and without molasses), the pH increased in the 2nd week and abruptly decreased in the 3rd week. The pH means ranged from 7.62 to 7.79.

The different hydroponic substrates revealed a negative effect on the volume of the remaining water. The means for this parameter ranged from 14.82 to 16.77 liters.

For the weight of the sediments collected during the termination, this parameter was influenced by the application of the different hydroponic nutrient solutions. Lettuce grown on T1 (SNAP) had the heaviest sediments collected, which was not statistically different from T4 (FON with chicken dung and without molasses) and T5 (with hog manure and without molasses). However, T4 was also found comparable to T2 (with chicken dung and molasses) and T3 (with cow manure and without molasses).

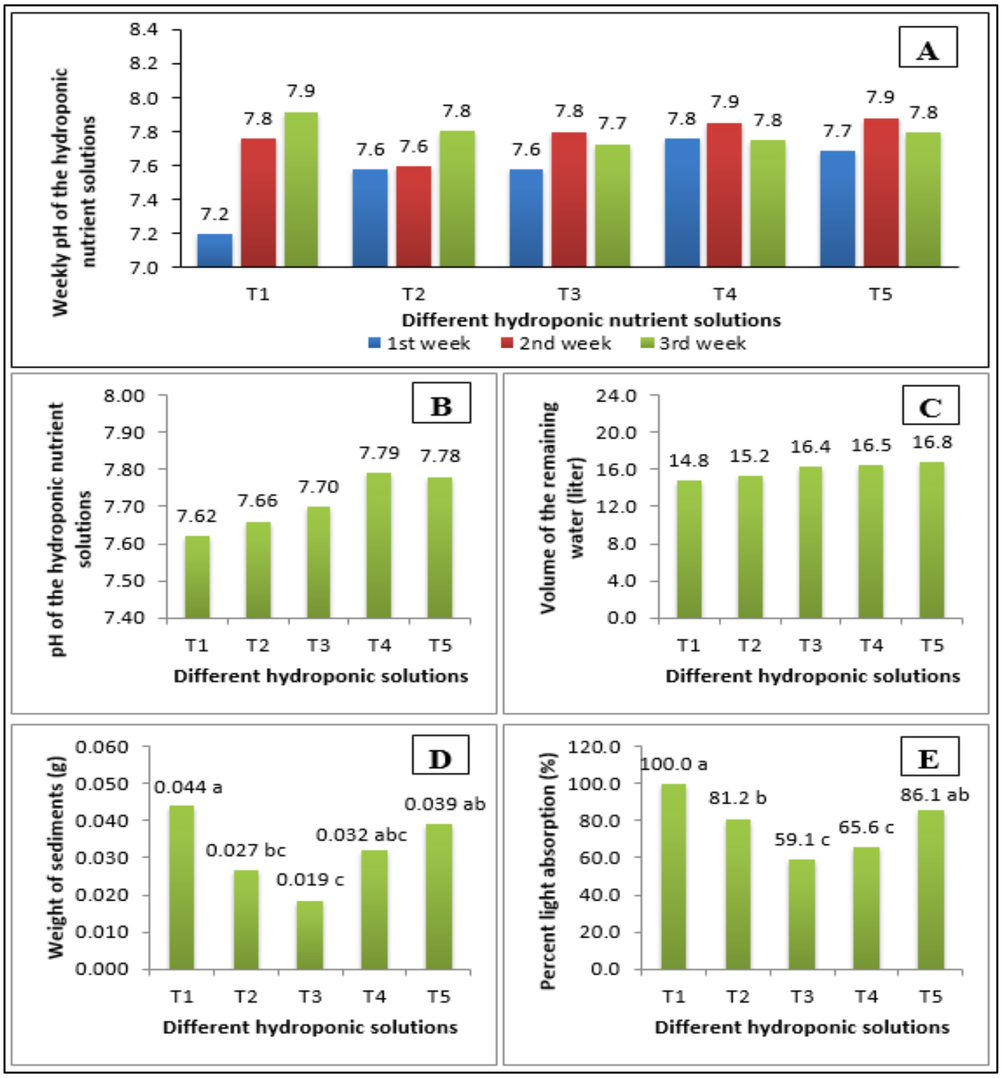

Figure 3. Weekly pH of hydroponic nutrient solutions (A), pH of the hydroponic nutrient solution (B), volume of the remaining water (C), weight of the sediments (D), and percent light absorption (E) as affected by the different formulated organic nutrient solutions T1– SNAP (control), T2 – FON with chicken dung and molasses, T3 – FON with cow manure and without molasses, T4 – FON with chicken dung and without molasses, and T5 – FON with hog manure and without molasses

The percent light absorption was also affected by the treatments. T1 (SNAP) absorbed the highest percent of light, which was similar to T5 (FON with hog manure and without molasses), and T5 was also found comparable to

T2 (FON with chicken dung and molasses). While the lowest percent of light was absorbed by the T3 (FON with cow manure and without molasses) and T4 (with chicken dung and without molasses).

Using the color wheel palette, it was noticed that lighter solutions obtained the highest percent of light absorption (Figure 9). The T1 solution was colorless, T5 was baby yellow, and T2 was gold ochre. However, the darker solutions were observed from T3 (color chocolate and chrome orange) and T4 (color of brown and red wood), which absorbed less light.

Figure 9. Color wheel palette

Discussion

Growth performance of lettuce to the different formulated organic nutrient solutions

The different hydroponic solutions significantly influenced the growth parameters of lettuce. Lettuce grown in T1 (SNAP) had the tallest plants, produced the most numbers of leaves, and had the widest and longest leaves. This aligns with the findings of Borres *et al.* (2022), who reported that the use of SNAP solution significantly impacted the height, leaf count, and both the width and length of lettuce leaves. However, this was not statistically different with the lettuce planted in the formulated organic nutrient solution T2 (FON with chicken dung and molasses). Similar to the study of Phibunwatthanawong and Riddech (2019), who concluded that lettuce applied with the organic liquid fertilizers had similar growth promotion properties as chemical fertilizer.

Moreover, the research by Solis and Magaret (2022) also confirms that the organic nutrient solution showed similar results to those of the conventional inorganic fertilizer, SNAP, regarding plant height, leaf width, leaf length, and leaf count. This is suggested that the formulated organic nutrient solution can be used as a hydroponic solution in growing lettuce as it performs similarly under favorable conditions. Among the formulated organic nutrient solutions, FON with chicken dung and molasses had a remarkable effect on the growth of lettuce. Suwor *et al.* (2020) found that chicken manure had the highest nutrient content and exhibited an optimal C/N ratio. They recommended chicken manure compost as an ideal option for lettuce cultivation.

Yield performance of lettuce with the different formulated organic nutrient solutions

The yield parameters of lettuce statistically differ with the different hydroponic solutions. The heaviest biomass and marketable and non-marketable parts were observed in the lettuce grown in T1 (SNAP). Borres *et al*. (2022) reported that the use of SNAP solution significantly influenced the yield of lettuce. This was found insignificant compared to the formulated organic nutrient solution (FON with chicken dung and molasses).

The findings of Phibunwatthanawong and Riddech (2019) is supported the feasibility of growing vegetables with organic nutrient solutions.

Additionally, Solis and Magaret (2022) reported that organic nutrient solutions had a highly significant impact on yield, including the number of marketable and non-marketable parts of lettuce, the weight of marketable heads per box, and the total yield per box. Hydroponic production significantly boosted yield and proved to be economically viable.

However, this contradicts the findings of Ahmed *et al*. (2021), who revealed that the overall growth and fresh biomass of lettuce grown with organic nutrient solutions were comparatively lower than those grown with inorganic nutrient solutions.

Net income over nutrient solutions cost of lettuce applied with the different hydroponic nutrient solutions

Among the hydroponic nutrient solutions used, lettuce applied with T1 (SNAP) obtained the highest gross income amounting to Php 1,313.66, followed by T2 (FON with chicken dung and without molasses), T4 (FON with chicken dung and without molasses), and T3 (FON with cow manure and without molasses) with the amounts of Php 793.80, Php 600.48, and Php 590.40, respectively. The lowest net income was recorded in the lettuce applied with T5 (FON with hog manure and without molasses), amounting to Php 531.00.

However, after deducting the solution cost and other production costs, the highest net profit was generated from T2 (Php 542.00), followed by T3 (Php 355.48). T1 generated a net income of Php 333.00, T5 has a net income of Php 286.00, and the lowest net income was generated from T4 (Php 245.00).

Solis and Magaret (2022) reported that the organic nutrient solution had a highly significant impact on the total yield per box of lettuce. They concluded that hydroponic production significantly increased yield and is economically viable.

Therefore, consider using FON with chicken dung in growing lettuce under hydroponic culture for a higher net income. FON with chicken dung and molasses exhibited a remarkable result, and should consider these economic outcomes when selecting substrates, balancing initial investment with potential returns.

Formulated nutrient solution (FON)

The pH of a hydroponic solution affects how well a plant can absorb essential nutrients. pH of the solution was not affected by the different hydroponic nutrient solutions. Based on the weekly analysis, the pH of the T1 (SNAP) and T2 (FON with chicken dung and molasses) increases every week, while for the T3 (FON with cow manure and without molasses), T4 (FON with chicken dung and without molasses), and T5 (FON with hog manure and without molasses), the pH increases in the 2nd week and abruptly decreases in the 3rd week. Solis and Magaret (2022) reported that the pH changes over time during the lettuce production.

In addition, the pH values of the FON ranged from 7.62 to 7.79. According to Brechner and Both (2013), the pH of a solution is crucial as it influences the availability of fertilizer salts. While a pH of 5.8 is considered optimal for the lettuce growing system described, a range of 5.6 to 6.0 is also acceptable. Nutrient deficiencies may arise if the pH falls outside the acceptable range.

Similarly, different hydroponic substrates revealed a negative influence on the volume of the remaining water. The means for this parameter ranged from 14.82 to 16.77 liters.

In terms of the weight of the sediments collected during the termination, this was influenced by the application of the different hydroponic nutrient solutions. The lettuce grown on T1 (SNAP) had the heaviest sediments collected, which was not statistically different from T4 (FON with chicken dung and without molasses) and T5 (with hog manure and without molasses). However, T4 was also found comparable to T2 (with chicken dung and molasses) and T3 (with cow manure and without molasses).

The treatments applied had also influenced the percent light absorption. T1 (SNAP) absorbed the highest percent of light, which was similar to T5 (FON with hog manure and without molasses), and T5 was also found comparable to T2 (FON with chicken dung and molasses). While the lowest percent of light was absorbed by the T3 (FON with cow manure and without molasses) and T4 (with chicken dung and without molasses).

Using the color wheel palette, it was noticed that lighter color substrates obtained the highest percent of light absorption. The T1 solution was colorless, T5 was baby yellow, and T2 was gold ochre. However, the dark-colored substrates were observed from T3 (chocolate and chrome orange color) and T4 (brown and red wood color), which absorb the lowest percent of light.

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Conflicts of interest

The authors declare no conflict of interest.

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