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Production Performance of Lettuce (*Lactuca Sativa* L. *var. Lalique*) Using Organic Nutrient Solution Under Hydroponic System

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ABSTRACT

This study evaluated the production performance of lettuce (*Lactuca sativa* L. *var. Lalique*) using organic nutrient solutions in a non-circulating hydroponic (Kratky) system. The experiment was conducted in a polyhouse at Camiguin Polytechnic State College, using a Randomized Complete Block Design (RCBD) with seven treatments: SNAP (synthetic control), Water (negative control), Vermitea, VegeGrow, Ramils, Biovoltin, and Healthynest. Growth parameters, yield components, nutrient solution consumption, sensory attributes, and profitability were assessed. Results indicated that Ramils (T5) and Healthynest (T7) performed comparably to SNAP (T1) in plant height, leaf width, canopy diameter, root development, and yield while also exhibiting high sensory quality and marketability. In contrast, T3 (Vermitea), T4 (VegeGrow), and T2 (Water) showed suboptimal performance, reflecting variability in organic fertilizer efficacy. The findings suggest that select organic nutrient solutions can be a viable alternatives to synthetic fertilizers in hydroponic lettuce production. However, further refinement of organic formulations is needed to improve stability and nutrient bioavailability. Further research is needed to assess long-term agronomic, economic, and environmental impacts. This study contributes to sustainable agriculture by supporting the integration of organic fertilizers into hydroponic systems.

INTRODUCTION

Lettuce (*Lactuca sativa* L.), locally referred to as "letsugas," is an annual crop belonging to the Asteraceae family and is widely recognized as one of the most commercially important salad vegetables (Jose, 2012). Lettuce exhibits optimal growth under cool climatic conditions, cultivation can be extended to diverse environments through the use of stress-tolerant cultivars (Maghirang *et al.,* 2012). Traditional open-field production systems, however, face significant challenges, such as limited arable land availability, soil degradation, declining fertility, water scarcity, pest and disease pressure, agrochemical dependency, and the escalating impacts of climate change (Diputado *et al.,* 2005; Majid *et al.,* 2021; Zailani *et al.,* 2019). These constraints contribute to reduced agricultural productivity (Morath, 2018) and diminished economic viability in crop production (Diputado *et al.,* 2005).

Hydroponics, a soilless cultivation system that utilizes nutrient-enriched aqueous solutions sustaining plant growth (Harahap *et al.,* 2020), offers a potential alternative. Despite its advantages in resource efficiency and sustainability, conventional hydroponic systems predominantly rely on synthetic fertilizers derived from non-renewable or fossil fuel-dependent processes, raising concerns regarding long-term environmental and economic sustainability. Furthermore, the discharge of fertilizer-laden effluent from these systems poses risks of ecological disruption and water contamination due to nutrient leaching. The integration of organic fertilizers has been proposed as a sustainable alternative (Lau & Mattson, 2021). Yet, limited empirical research has investigated their efficacy in passive hydroponic systems such as the Kratky method.

This study therefore seeks to address this research gap by evaluating the feasibility and performance of organic fertilizers in Kratky-based hydroponic lettuce production. Generally, this study was conducted to evaluate commercially available organic nutrient solutions by comparing them to commercial inorganic fertilizers for the production of lettuce. Specifically, the study aimed to: 1.) evaluate the growth performance of lettuce, 2.) determine the yield and its components, 3.) assess the nutrient solution consumption and quality, 4.) evaluate sensory quality attributes of lettuce, and 5.) determine the profitability of lettuce production using different organic nutrient solutions.

MATERIALS AND METHODS

Study Area

The crop experiment was carried out in a plastic polyhouse with mesh net at the Institute of Agriculture, Camiguin Polytechnic State College – Catarman Campus, Tangaro, Catarman, Camiguin from October 18, 2021 to December 1, 2021 It is situated at 9º 07.019' N latitude and 124º41.240' E longitude and an elevation of 180 m above mean sea level. Natural solar radiation is the only source of light inside the polyhouse with natural ventilation.

Materials

The materials used in the study were: lettuce seeds (*Lactuca sativa* L. var *Lalique*), seedling tray, hydroponics

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nutrient solution, sphagnum peat moss, coco peat, 34.5 in x 17 in x 7 in styro boxes, 20 cm x 30 cm x 0.003 mm polyethylene plastic sheets, plastic styrofoam cups, packaging tape, digital pH, TDS, pH buffer solution, pH adjuster, 200 ml beaker, 25 ml graduated cylinder, digital weighing scale, pipette, stirring rod, vernier caliper, ruler, scissor, and plastic drum.

Experimental Design and Treatments

The experiment was laid out in a Randomized Completely Block Design (RCBD) with seven (7) treatments and three (3) replications at 15 plants per treatment. The following were the treatments: SNAP (Positive Control), Water (Negative Control), Vermitea, VegeGrow, Ramils, Biovoltin, and Healthynest.

Cultural Management and Practices

The various cultural management and practices were based on the study of Solis and Magaret (2023) which includes seedling establishment, seedling plugs preparation, growing boxes preparation, operation of hydroponics system, application of treatment, insect pest and disease control, and harvesting.

Data Gathered

The data gathered were plant height, leaf width, leaf blade length, canopy diameter, number of leaves per plant, root length, root volume, root fresh weight, total fresh weight, percentage roots per plant, survival rate, number of marketable and non-marketable head, head fresh weight (marketable and non-marketable), total yield, harvest index, nutrient solution consumption per plant, total nutrient solution consumption, pH, total dissolved solids (TDS), sensory quality attributes and marketability, and cost and return analysis as described by Solis and Denzo (2024).

Statistical Tools and Analysis

The data gathered was analyzed using ANOVA by the Statistical Tool for Agricultural Research (STAR) version 2.0.1 software and it was compared using Tukey's Test at 5% level of significance.

RESULTS AND DISCUSSION

Horticultural Characteristics

The use of organic nutrient solutions in hydroponic lettuce production has shown significant and mixed effects on growth parameters. T7 (Healthynest) and T5 (Ramils) consistently performed well across most parameters, including plant height, leaf width, leaf blade length, canopy diameter, and number of leaves (Table 1). This result aligns with the findings of Chowdhury, Samarakoon and Attland (2024) and Ezziddine, Liltved and Seljasen (2021) that organic fertilizers can support robust growth, provided microbial mineralization is efficient. These solutions likely mimic the benefits of synthetic fertilizers by delivering bioavailable nitrogen and phosphorus, critical for leaf expansion and canopy development (Ezziddine *et al.,* 2021; Park & Williams, 2023). T1 (Snap) also showed strong results in plant height, leaf blade length, and number of leaves, but had a significantly smaller canopy diameter compared to T5 (Ramils) and T7 (Healthynest). T6 (Biovoltin) showed intermediate growth while T2 (Water), T3 (Vermitea), and T4 (VegeGrow) showed poor performance, suggesting it may not be suitable for lettuce growth. T2 (Water) and T4 (VegeGrow) showed minimal growth, indicating that water alone or VegeGrow may not provide sufficient nutrients for optimal lettuce development. Minimal growth underscores hydroponic lettuce requires supplemented nutrients; water alone lacks essential macro/micronutrients. Poor performance may stem from inadequate nutrient composition or phytotoxic compounds in unprocessed organic sources, as seen with some compost teas or vermicompost extracts that inhibit root development (Chowdhury *et al.,* 2024; Gent, 2017). Organic solutions may lead to variability in leaf dimensions and plant height due to slower nutrient mineralization and challenges in maintaining stable nutrient solution quality (Ezziddine *et al.,* 2021; Hooks *et al.,* 2022).

Table 1: Horticultural characteristics of lettuce 45 days after seed sowing as affected by different organic nutrient solution

Treatment	Plant height (cm)	Leaf width (cm)	Leaf blade length (cm)	Canopy diameter (cm)	Number of leaves
T1 - Snap Solution	13.20[a]	3.83[ab]	8.99[a]	1.74[c]	10.47[a]
T2 - Water	2.75[c]	0.68[c]	1.63[c]	1.94[c]	5.00[bc]
T3 - Vermitea	0.24[c]	0.21[c]	0.16[c]	0.07[c]	0.90[c]
T4 - VegeGrow	2.30[c]	0.57[c]	0.83[c]	15.06[a]	3.47[bc]
T5 - Ramils	13.55[a]	4.16[a]	9.43[a]	16.40[a]	11.97[a]
T6 - Biovoltin	6.22[b]	2.41[b]	5.58[b]	8.86[b]	5.57[b]
T7 - Healthynest	14.15[a]	4.62[b]	9.30[a]	16.38[a]	12.37[a]
$HSD_{\alpha 0.05}$	**	**	**	**	**
CV (%)	15.73	24.27	16.20	19.50	21.91

Mean followed by the same letter in the same column are not significantly different at the level of α = 0.05 based on Tukey's Honest Significant Difference (HSD) Test. *significant, **highly significant, nsnon-significant.

Horticultural Root Development Characteristics and Survival Rate

Table 2 presents the root development characteristics and survival rate of lettuce plants 45 days after sowing as affected by different organic nutrient solution. T5 (Ramils) and T7 (Healthynest) consistently performed well in root length, root volume, root fresh weight, and total fresh weight, similar to their strong performance in growth performance. T5 (Ramils) exhibited longest roots (31.77 cm), high root volume (5.25 mL), and strong root fresh weight (7.50 g). T7 (Healthynest) has the highest root volume (5.59 mL) and root fresh weight (8.50 g), indicating excellent nutrient uptake. T1 (Snap Solution) also performed well but had lower root volume (4.08 mL) compared to T5 and T7. T6 (Biovoltin) showed decent root length (28.42 cm) but lower root volume (2.80 mL) and fresh weight (4.04 g) compared to top treatments. Survival rate (67%) was lower, suggesting possible stress or nutrient imbalance affecting plant health. T3 (Vermitea) had extremely poor root development (0.12 cm length, 0.17 mL volume) and 13% survival, confirming its unsuitability for lettuce growth. T2 (Water, control) and T4 (VegeGrow) had minimal root growth and low total fresh weight (2.00 g), reinforcing that water alone or VegeGrow is insufficient for robust lettuce production.

Table 2: Horticultural root development characteristics and survival rate of lettuce 45 days after seed sowing as affected by different organic nutrient solution

Treatment	Root length (cm)	Root volume (mL)	Root fresh weight (g)	Total fresh weight (g)	Percentage root per plant (%)	Survival rate (%)
T1 – Snap	31.12[ab]	4.08[bc]	5.54[ab]	60.46[a]	9.67[c]	100[a]
T2 - Water	11.21[cd]	1.04[d]	1.00[c]	2.00[b]	50.00[a]	100[a]
T3 - Vermitea	0.12[d]	0.17[d]	0.12[c]	0.25b	50.00[a]	13[b]
T4 - VegeGrow	13.51[bcd]	1.00[d]	1.00[c]	2.00[b]	50.00[a]	100[a]
T5 - Ramils	31.77[a]	5.25[ab]	7.50[a]	58.58[a]	13.33[c]	100[a]
T6 - Biovoltin	28.42[abc]	2.80[c]	4.04[b]	15.04[b]	28.33[b]	67[a]
T7 - Healthnest	25.10[a]	5.59[a]	8.50[a]	59.12[a]	14.33[c]	100[a]
$HSD_{\alpha 0.05}$	**	**	**	**	**	**
CV (%)	30.87	16.39	26.62	38.71	9.92	26.96

*Mean followed by the same letter in the same column are not significantly different at the level of a = 0.05 based on Tukey's Honest Significant Difference (HSD) Test. *significant, **highly significant, nsnon-significant.*

Yield Parameters

The data presented in Table 3 presents the impact of organic nutrient solutions on lettuce yield parameters 45 days after seed sowing. The results reveal significant differences in fresh head weight, marketable yield, non-marketable yield, total yield, and harvest index among treatments. T1 (Snap) demonstrated superior results in fresh head weight (54.92 g), number (7.67) and weight marketable yield (54.30 g), total yield (439.33 g), and harvest index (90%). Synthetic nutrient solutions like SNAP (Simple Nutrient Addition Program) often outperform organic alternatives in terms of yield and uniformity. For instance, a study on hydroponic lettuce found that 100% SNAP solution produced the highest number of leaves (10.30), largest canopy (24.50 cm), and highest plant weight (51.23 g) compared to organic treatments (Solis &

Table 3: Yield parameters of lettuce 45 days after seed sowing as affected by different organic nutrient solution

Treatment	Fresh head weight $plant^{-1}$ (g)	Marketable head		Non-marketable head		Total Yield (g box^{-1})	Harvest Index (%)
		Number	Weight (g box^{-1})	Number	Weight (g box^{-1})		
T1-Snap	54.92[a]	7.67[a]	54.30[a]	0.33[b]	0.42[b]	439.33[a]	90.00[a]
T2-Water	1.00[b]	0.00[b]	0.00[b]	8.00[a]	8.00[b]	8.00[b]	50.00[c]
T3-Vermitea	0.12[b]	0.00[b]	0.00[b]	1.00[b]	0.12[b]	1.00[b]	50.00[c]
T4-VegeGrow	1.00[b]	0.00[b]	0.00[b]	8.00[a]	1.00[b]	8.00[b]	50.00[c]
T5-Ramils	51.08[a]	7.67[a]	50.29[a]	0.33[b]	0.79[a]	408.67[a]	86.67[a]
T6-BioVoltin	11.00[b]	0.00[b]	0.00[b]	6.00[a]	1.00[a]	88.00[b]	70.67[b]
T7-Healthynest	50.62[a]	7.00[a]	47.46[a]	1.00[b]	3.17[b]	405.00[a]	86.67[a]
$HSD_{\alpha 0.05}$	**	**	**	**	**	**	**
CV (%)	43.85	10.07	50.43	38.76	84.75	43.85	4.45

*Mean followed by the same letter in the same column are not significantly different at the level of a = 0.05 based on Tukey's Honest Significant Difference (HSD) Test. *significant, **highly significant, nsnon-significant.*

Margaret, 2022). This can be attributed to the consistency of synthetic fertilizers in providing readily available nutrients results in higher harvest indices and marketable yields. Organic nutrient solutions, T5 (Ramils) and T7 (Healthynest) also demonstrated comparable results. For example, liquid organic fertilizers derived from distillery slop and sugarcane leaves showed growth performance comparable to chemical fertilizers in hydroponic lettuce (Upendri & Karunarathna, 2021). T3 (Vermitea), T4 (VegeGrow), and T6 (BioVoltin) produced no marketable heads which highlights the variability in organic fertilizer efficacy. The failure of these treatments to produce marketable heads may stem from nutrient imbalances or slower mineralization rates (Ramos *et al.,* 2024).

Nutrient Solution Consumption and Quality

The choice of organic nutrient solution significantly affects nutrient solution consumption and its quality as shown in Table 4. T6 (BioVoltin) had the highest nutrient solution consumption per plant (4.99 L) and T4 (VegeGrow) the highest total nutrient solution consumption while T5 (Ramils) had the lowest nutrient solution consumption per plant (3.28 L) and T3 (Vermitea) the lowest total nutrient solution consumption (4.17 L). Throughout the lettuce production process, both pH levels and total dissolved solids (TDS) exhibit dynamic variations over time. Initially, pH at 0 DAT, T2 (Water) was significantly higher (8.98) and T1 (Snap) and T3 (Vermitea) were the lowest (5.73 and 5.17, respectively). At later stages (31DAT), T2 (Water), T4 (VegeGrow), and T6 (BioVoltin) maintained near-neutral to slightly alkaline pH (7.08–7.52). Most treatments showed pH stabilization over time, but T1 (Snap) and T5 (Ramils) remained acidic (6.38 & 6.39). An optimal pH of 5.5-6.5 is required for hydroponic lettuce production to ensure maximum nutrient availability, as lettuce absorbs essential minerals best in slightly acidic conditions (Santos *et al.,* 2024). A pH below 5.5 may cause nutrient deficiencies (e.g., calcium), while above 6.5 can lead to iron and manganese lockout. Also, initially (0 DAT), T1 (Snap) had the highest TDS (1675.33 ppm), while T2 (Water) was lowest (225.33 ppm). At later stages (31 DAT), T6 (BioVoltin) and T5 (Ramils) retained higher TDS, whereas T2 (Water) and T3 (Vermitea) had the lowest. An optimum TDS of 560 to 840 ppm (Rafi, Sarosa, & Sumari, 2024) is required. For hydroponic lettuce, maintaining the correct pH and TDS (Total Dissolved Solids) levels is crucial for optimal growth.

Sensory Quality Attributes and Marketability of Lettuce

Table 5 presents the sensory evaluation and marketability of lettuce treated with different organic nutrient solutions 45 days after seed sowing. A highly significant variation was observed on the sensory quality attributes and marketability of lettuce. T5 (Ramils) consistently scored the highest across all attributes (Color, Appearance, Aroma, Crispness, Succulence, Overall Texture, Overall Flavor, Overall Acceptability, and Marketability). T7 (Healthynest) was the second best, performing well in most attributes but slightly lower than T5 in some categories. T1(Snap) had moderate scores but was significantly lower than T5 and T7. T5 (Ramils) had the highest bitterness (3.67), but since bitterness is not necessarily negative in lettuce (some consumers prefer slight bitterness), it did not negatively impact overall acceptability. T6 (BioVoltin) and T7 (Healthynest) had lower bitterness, which may explain why their overall flavor scores were slightly lower than T5 (Ramils). On marketability, T5 (Ramils) had the highest marketability, meaning consumers were most likely to purchase it. T7 (Healthynest) and T6 (BioVoltin) followed, while T1 (Snap) was significantly lower. T2 (Water), T3 (Vermitea), and T4 (VegeGrow) were rated very poorly, indicating they are not marketable.

Table 4: Nutrient solution consumption and quality of nutrient solution of lettuce 45 days after seed sowing as affected by different organic nutrient solution

Treatment	Nutrient solution consumption plant-1	Total nutrient consumption	pH					TDS				
	(L)	(L)	0	7 DAT	14 DAT	21 DAT	31 DAT	0	7 DAT	14 DAT	21 DAT	31 DAT
T1-Snap	3.53	28.23^{a}	5.73^{d}	5.91^{bc}	6.34^{b}	5.62^{b}	6.38^{c}	1675.33^{a}	920.67^{a}	106.33^{bc}	502.67^{ab}	500.00^{a}
T2-Water	3.51	28.06^{a}	8.98^{a}	6.69^{ab}	7.25^{ab}	7.64^{a}	7.52^{a}	225.33^{d}	57.00^{b}	48.33^{c}	53.00^{b}	49.67^{d}
T3-Vermitea	4.17	4.17^{b}	5.17^{d}	5.23^{c}	6.86^{ab}	7.47^{a}	7.08^{abc}	869.00^{bcd}	227.67^{ab}	229.33^{a}	283.33^{ab}	128.67^{cd}
T4-VegeGrow	3.71	29.72^{a}	7.33^{b}	7.32^{a}	7.46^{a}	8.08^{a}	7.43^{a}	475.67^{cd}	127.33^{ab}	114.67^{b}	128.00^{ab}	105.67^{cd}
T5-Ramils	3.28	26.28^{a}	7.00^{b}	6.81^{ab}	6.60^{ab}	6.30^{b}	6.39^{c}	1007.33^{bc}	315.67^{ab}	238.33^{a}	272.67^{ab}	180.67^{bc}
T6-BioVoltin	4.99	24.35^{a}	6.83^{bc}	6.91^{ab}	7.09^{ab}	7.70^{a}	7.15^{ab}	1318^{ab}	296.00^{ab}	287.33^{a}	357.67^{a}	275.33^{b}
T7-Healthynest	3.38	27.01^{a}	6.67^{bc}	6.50^{ab}	6.55^{ab}	6.12^{b}	6.52^{bc}	977.67^{bc}	321.67^{ab}	244.67^{a}	262.00^{ab}	109.67^{cd}
$HSD_{\alpha 0.05}$	ns	**	**	*	**	**	**	**	**	**	**	**
CV (%)	27.55	14.18	5.79	6.35	4.90	3.79	3.60	24.63	1.11	12.69	5.92	19.93

*Mean followed by the same letter in the same column are not significantly different at the level of a = 0.05 based on Tukey's Honest Significant Difference (HSD) Test. *significant, **highly significant, non-significant.*

Table 5: Sensory quality attributes of lettuce and marketability 45 days after seed sowing as affected by different organic nutrient solution

Treatment	Color	Appearance	Aroma	Crispness	Succu-lence	Overall Texture	Bitterness	Overall Flavor	Overall Acceptability	Marketability
T1-Snap	4.01^{d}	3.34^{d}	3.01^{d}	3.34^{c}	3.68^{c}	3.34^{c}	3.34^{b}	3.01^{c}	2.34^{c}	3.01^{d}
T2-Water	1.03^{e}	1.03^{e}	1.03^{e}	1.03^{d}	1.03^{e}	1.03^{d}	1.03^{e}	1.03^{d}	1.03^{d}	1.03^{e}
T3-Vermitea	1.02^{e}	1.02^{e}	1.02^{e}	1.02^{d}	1.02^{e}	1.02^{d}	1.02^{e}	1.02^{d}	1.02^{d}	1.02^{e}
T4-VegeGrow	1.12e	1.12^{e}	1.12^{e}	1.12^{d}	1.12^{e}	1.12^{d}	1.12^{e}	1.12^{d}	1.12^{d}	1.14^{e}
T5-Ramils	4.33^{a}	4.67^{a}	4.67^{a}	4.67^{a}	4.67^{a}	4.67a	3.67^{a}	4.67^{a}	4.67^{a}	5.00^{a}
T6-BioVoltin	3.38^{c}	3.72^{c}	3.38^{c}	3.38^{c}	3.38^{d}	3.38^{c}	1.38^{d}	3.38^{b}	3.38^{b}	3.72^{c}
T7-Healthynest	4.45^{b}	4.45^{b}	4.45^{b}	4.45^{b}	4.45^{b}	4.45^{b}	2.12^{b}	3.45^{b}	3.45^{b}	4.45^{b}
$HSD_{\alpha 0.05}$	**	**	**	**	**	**	**	**	**	**
CV (%)	2.49	2.49	2.58	2.53	2.49	2.53	3.52	2.72	10.50	10.50

Consumer acceptability scores on a 5-point hedonic scale (Scale: 1-dislike extremely; 2-dislike slightly; 3-neither like nor dislike; 4-like slightly; 5-like extremely)

*Mean followed by the same letter in the same column are not significantly different at the level of a = 0.05 based on Tukey's Honest Significant Difference (HSD) Test. *significant, **highly significant, non-significant.*

CONCLUSION

This study confirms the viability of organic nutrient solutions in hydroponic lettuce production, with T5 (Ramils) and T7 (Healthynest) performing comparably to the synthetic control T1 (Snap) in growth, yield, and sensory quality. These organic formulations facilitated effective nutrient uptake and plant development, demonstrating their potential as sustainable alternatives to conventional fertilizers. However, the suboptimal performance of Vermitea, VegeGrow, and Water highlights the variability in organic fertilizer efficacy, necessitating improved formulation stability and nutrient bioavailability. Maintaining optimal pH and total dissolved solids (TDS) proved critical for consistent hydroponic productivity across treatments. Future research should prioritize refining organic nutrient compositions and assessing their long-term agronomic, environmental, and economic impacts to support scalable adoption.

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