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HYDROPONIC LETTUCE *(Lactuca sativa* L. var. *Lalique)* PRODUCTION USING COMMERCIALLY AVAILABLE NUTRIENT SOLUTIONS

[1*]Erecson Sipin Solis, [2]Junamae U. Gabutan

[1,2]Institute of Agriculture, Camiguin Polytechnic State College-Catarman Campus, Tangaro, Catarman, Camiguin, Philippines.

*Corresponding author

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ABSTRACT

This study was carried out to assess commercially available nutrient solutions (Yamasaki, MaterBlend, Snap, Nutrihydro, and Hydroplus) in hydroponic lettuce production in comparison to organic fertilizers (Biovoltin) with water as a negative control. The crop experiment was conducted at the Institute of Agriculture, Camiguin Polytechnic State College-Catarman Campus, Tangaro, Catarman, Camiguin, from January 25, 2022, until March 10, 2022. The study was laid in a Randomized Complete Block Design with seven (7) treatments and three (3) replications at eight plants per treatment. Results of the study showed that considering horticultural growth and root characteristics, lettuce grown on Masterblend produced taller plants, longer leaf blades, and wider canopy, SNAP exhibited broader leaves, and Yamasaki with the greater number of leaves, longer roots, higher root volume, root fresh and total fresh weight while all treatment exhibited a 100% survival rate. In terms of yield, Masterblend had the higher fresh head weight per plant, the weight of marketable head per box, and total yield, Yamasaki, Masterblend, SNAP, and Hydroplus had a higher number of marketable yields, and Hydro plus had a higher harvest index. SNAP was considered best overall in terms of sensory quality attributes and marketability. Using the SNAP solution resulted in higher net return, net profit margin, and return on investment, followed by Masterblend, Hydroplus, and Yamasaki. It can be 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.

Keywords: Growth, hydroponics, lettuce, inorganic nutrient solution, yield

1. INTRODUCTION

Lettuce (*Lactuca sativa* L.) is considered as one of the most popular leafy vegetable for fresh consumption (Girma et al., 2020) and belongs to the *Asteraceae* family (Ahmed et al., 2021). It is rich in fiber (Khodijah et al., 2021), a good source of health-promoting compounds such as vitamins (A, C, Iron, K, and folate) (Mulabagal et al., 2010; Kim et al., 2016), nutrients and minerals, and anticarcinogenic antioxidants (quercetin, caffeic acid and lactupicrin) (Chiesa et al., 2009) which are beneficial to human health. Among the hydroponically grown crops, lettuce is the most widely grown vegetables in a soilless system (Ahmed et al., 2021) and reports have shown that under this system it has a high yield and good quality (Kaiser & Ernst, 2012; Qadeer et al., 2020).

Hydroponics system is a cultivation technique that involves growing crops without soil, using mineral nutrient solutions in an aqueous solvent (Santos & Ocampo, 2005) and a growing media (Saradre & Admane, 2013). This system also contributes to sustainable production of vegetables as it allows the growers for a continuous production in a short growing period and requires less space (Aires, 2018), higher production and yields without any constraints of climate and weather conditions (Ekoungoulou et al., 2018), and superior quality of crops and homogenous production under a highly controlled environment (Nguyen et al., 2016). Also, the susceptibility of vegetables to weeds, insect pests, and diseases are lessened (Baez & Manipon, 2000) under hydroponics system and has a lower cost during planting, growing, and harvesting of crops (Hassall et al., 1993).

In hydroponics system, all nutritional requirements of the crop are made available by supplying with water enriched with minerals (Qadeer et al., 2020). The availability of these nutrients in the growing medium and quantity of the amount of nutrients that can be readily absorbed by the crops greatly influenced the growth rate of hydroponic lettuce (Nguyen & Tran, 2020). The selection of available nutrient solution and its appropriate control for an effective nutritional management can consequently increase hydroponics lettuce yield (Da Genuncio et al., 2012); hence this study was conducted. Generally, this study was conducted to evaluate commercially available inorganic nutrient solutions in comparison to commercial organic fertilizer in the production of lettuce. Specifically, itaimed 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.

2. METHODOLOGY

2.1 Experimental Site

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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, Camiguinfrom January 25, 2022 until March 10, 2022. It was 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 was the only source of light inside the polyhouse with natural ventilation.

2.2 Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Blocked Design (RCBD) with seven (7) treatments and three (3) replications at 15 plants per treatment. The treatments were:T1 – Biovoltin (Positive Control); T2 – Water (Negative Control) ; T3 – Yamasaki; T4 – Masterblend; T5 – SNAP; T6 –Nutrihydro; and T7 – Hydroplus.

2.3 Cultural Management

2.3.1. Seedlings Establishment

The seedling tray was filled with coco peat, then was packed and levelled. Seeds of lettuce (one seed per hole) were sown in the seedling tray and placed under the shaded area. Watering was done liberally every day. Germination started three to five days after seed sowing. The seedling was hardened by gradual exposure to sunlight (from day eight to fourteen) and the introduction of half strength of the nutrient solution. After 14 days, seedlings were transferred to individual growing cups (seedling plugs).

2.3.2. Seedling Plugs Preparation

Using a serrated knife or saw, four to six slits were made (about two inches long on the side and one-half inch at the bottom) on the Styrofoam cups. The growing cups were then filled with the growing media about one inch thick. Growing media were sterilized either by solarization or by adding boiled water to it. A hole was dug in the middle of the growing media in the cup. Using a bamboo stick, the seedlings from the seedling tray were uprooted and transplanted into the seedling plug (one seedling per cup). The growing media around the base of the transplanted seedling were lightly pressed, and the seedling plug was watered carefully. For the foam, a one-inch by one-inch dimension was prepared, and a cut of a one-half inch was made. Seedlings were then just inserted into the cut section of the foam.

2.3.3. Growing Boxes Preparation

Using a tin can borer, eight holes were made on the Styrofoam (47 cm x 31 cm x 2.54 cm). Polyethylene plastic bag was used as a liner to the bottom of the empty plastic soda box (inside

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plastic casing removed) and was fitted for holding the nutrient solution. Using packaging tape, all the slits and endpoints were secured to prevent the entry of mosquitoes.

2.3.4. Growing Boxes Preparation

Using a tin can borer, eight holes were made on the Styrofoam (47 cm x 31 cm x 2.54 cm). Polyethylene plastic bag was used as a liner to the bottom of the empty plastic soda box (inside plastic casing removed) and was fitted for holding the nutrient solution. Using packaging tape, all the slits and endpoints were secured to prevent the entry of mosquitoes.

2.3.5. Operation of Hydroponics System

The hydroponics system was located in an area where it received the morning sunlight (earlier and longer) under a polyethylene house. The growing boxes were linearly arranged on a level bench with covers removed. Each growing box was then filled with 32liters of tap water. Nutrient solution was added according to the dilution recommended and was stirred thoroughly. The cover/lid was then placed over the boxes. Seedling plugs were then inserted into the holes of the lid/cover, making sure that all were properly plugged in the holes. The bottom of the seedling plug was checked in order to ensure that it touched the nutrient solution by one-half inch, not deeper or shallower. If not, the addition of tap water was done until the desired depth was reached. Leaks were then examined, and if there were necessary, troubleshooting was done.

2.3.6. Insect Pest and Disease Control

The researcher visited the experimental set-up daily, especially early in the morning, to monitor the presence of insect pests and diseases. Insect pests that can be hand-picked were removed manually. Another option was to spay a mixture of food-grade Hydrogen Peroxide (H_2O_2) to water (10 ml H_2O_2 to 1 L water).

2.3.7. Harvesting

Harvesting was done early in the morning where there is less transpiration and avoiding moisture loss of the leafy vegetable. Lettuce was harvested 45 days after seed sowing or 31 days after transplanting.

2.4. Data Gathered

Data collection was done during the harvest period. Lettuce plants were harvested and data on horticultural characteristics such as 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 of roots per plant, and survival rate were collected. The yield and yield component

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data such as the number and weight of marketable and non-marketable heads, total yield, and harvest index were determined right after harvesting. Nutrient solution consumption and its quality were also gathered. The consumer acceptability and marketability and cost and return analysis were also gathered and determined.

2.5 Statistical Tools and Analysis

The data gathered was analyzed using ANOVA by the Statistical Tool for Agricultural Research (STAR) version2.0.1 software and it was compared using Tukey's Test at5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Horticultural Characteristics

The type of nutrient solutions had significantly affected the horticultural characteristics of lettuce plants (Table 1).Lettuce grown on Masterblend produced taller plants, longer leaf blade, wider canopy, SNAP exhibited broader leaves, and Yamasaki with the greater number of leaves while BioVoltin produced narrower leaves, shorter leaf blade, narrower canopy and lesser number of leaves. This result confirms the study of Ramos (2022), Santiago (2021) and Borres et al. (2022) who reported that using commercially available inorganic nutrient solution (SNAP & Masterblend) had the optimum level of nutrients for horticultural growth and development. Using organic nutrient solution exhibited poor performance compared to using chemical nutrient solution as reported by Santiago (2021) and Phibun watthana wong & Riddech (2019).

Table 1: Horticultural characteristics of lettuce 31 days after transplanting as affected by different commercially available nutrient solution.

Treatment	Plant height (cm)	Leaf width (cm)	Leaf blade length (cm)	Canopy diameter (cm)	Number of leaves
BioVoltin	0.50^{b}	0.69^{b}	1.32^{b}	0.50^{b}	3.38^{b}
Water	0.71^{b}	1.30^{b}	2.90^{b}	0.71^{b}	5.17^{b}
Yamasaki	4.64^{a}	7.21^{a}	16.51^{a}	4.64^{a}	19.79^{a}
Masterblend	4.74^{a}	6.80^{a}	16.71^{a}	4.74^{a}	19.48^{a}
Snap	3.73^{a}	7.81^{a}	16.10^{a}	3.73^{a}	18.12^{a}
NutriHydro	4.18^{a}	7.63^{a}	15.57^{a}	4.18^{a}	16.75^{a}
Hydroplus	4.27^{a}	6.99^{a}	15.98^{a}	4.27^{a}	16.88^{a}
$HSD_{\alpha 0.05}$	**	**	**	**	**
CV (%)	12.8	21.44	7.94	12.8	19.74

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, non-significant.

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3.2 Horticultural root development characteristics andsurvival rate

Table 2 shows that a highly significant variation was observed on the root length, root volume, root fresh weight, total fresh weight, and percentage root per plant while no significant variation found on survival rate. Yamasaki exhibited longer roots, higher root volume, root fresh and total fresh weight, Water with higher percentage root per plant and all treatment exhibited a 100% survival rate. Biovoltin exhibited shorter roots, lighter root volume, root fresh weight, and total fresh weight, and Hydroplus with lower percentage rootper volume. Using inorganic nutrient solution in a hydroponic system, the root zone has a very low oxygen biological demand as compared to organic nutrient solution due to the presence of organic carbon compounds (Ezzidine et al., 2021). Limited aeration reduces root formation and development. The availability of dissolved oxygen greatly affects the root formation and root growth (Soffer & Burger, 1998).

Table 2: Horticultural root development characteristics and survival rate of lettuce 31 days after transplanting as affected by different commercially available nutrient solution.

Treatment	Root length (cm)	Root volume (mL)	Root fresh weight (g)	Total fresh weight (g)	Percentage root per plant (%)	Survival rate (%)
BioVoltin	5.17^{b}	2.29^{b}	1.57^{c}	3.17^{c}	54.63^{a}	100
Water	25.62^{b}	4.79^{b}	2.51^{c}	$4.46b^{c}$	72.00^{a}	100
Yamasaki	33.19^{a}	47.71^{a}	24.17^{a}	25.17^{a}	21.00^{b}	100
Masterblend	28.83^{a}	40.34^{a}	19.63^{ab}	20.29^{a}	17.67^{b}	100
Snap	31.90^{a}	46.46^{a}	22.32^{a}	24.39^{a}	17.67^{b}	100
NutriHydro	28.90^{a}	45.21^{a}	21.23^{ab}	27.10^{a}	23.67^{b}	100
Hydroplus	28.06^{a}	40.84^{a}	15.32^{b}	16.32^{ab}	16.67^{b}	100
$HSD_{\alpha 0.05}$	**	**	**	**	**	ns
CV (%)	12.15	13.78	15.98	25.68	19.2	NaN

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, non-significant.

3.3 Yield Parameters

The type of nutrient solution had a highly significant effect on the fresh weight, number of marketable and non market head of lettuce, weight of marketable head perbox, total yield per box, and harvest index. However, no significant difference was observed on non-marketable head per box.

Masterblend had the higher fresh head weight per plant, weight of marketable head per box, and total yield, Yamasaki, Masterblend, SNAP and Hydroplus had higher number of marketable

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yield, Hydroplus had higher harvest index, Biovoltin and Water with higher number of non-marketable head and NutriHydro with the higher non-marketable head weight per box. Water had lower fresh head weight per plant, total yield, and harvest index, and lettuce harvested from Biovoltin and Water were all non-marketable hence, had lower number and weight per box of marketable head. It was reported by William and Nelson (2014) using conventional inorganic fertilizer cultivation produced heavier of fresh weight as compared to lettuce grown in organic nutrient solution. This is also confirmed by the study of Santiago (2019) plants grown in commercially available nutrient solution (SNAP) consistently produced the heaviest fresh weight per plant.

Table 3: Yield parameters of lettuce 31 days after transplanting as affected by different commercially available 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})		
BioVoltin	1.21^{b}	0.00^{b}	0.00^{b}	8.00^{a}	1.21	8.27^{b}	29.00^{b}
Water	0.99^{b}	0.00^{b}	0.00^{b}	8.00^{a}	0.99	7.57^{b}	16.33^{b}
Yamasaki	90.38^{a}	8.00^{a}	90.38^{a}	0.00^{b}	0	723.07^{a}	65.67^{a}
Masterblend	93.22^{a}	8.00^{a}	93.22^{a}	0.00^{b}	0	745.73^{a}	70.00^{a}
Snap	73.24^{a}	8.00^{a}	73.24^{a}	0.00^{b}	0	585.93^{a}	60.33^{a}
NutriHydro	73.67^{a}	6.33^{a}	68.80^{a}	1.67^{b}	4.87	589.33^{a}	62.00^{a}
Hydroplus	75.85^{a}	8.00^{a}	75.85^{a}	0.00^{b}	0	606.77^{a}	71.33^{a}
$HSD_{\alpha 0.05}$	**	**	**	**	ns	**	**
CV (%)	26.66	19.92	30.99	43.23	316.04	26.69	14.3

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

3.4 Nutrient solution consumption and quality

Different nutrient solutions exhibited highly significant effects on nutrient solution consumption and quality except for pH at 7 DAT (Table 4). Biovoltin has the highest nutrient solution consumption per plant and total nutrient solution consumption with Nutrihydro and Hydroplus the lowest, respectively. The pH and total dissolved solids (TDS) vary over time during the lettuce production. The pH of the nutrient solution controls the availability of the fertilizer salts and TDS on the other hand refers to the available salts and nutrients in the water. For lettuce, a pH value of 5.6-5.8 is considered optimum and a TDS of 560-840 ppm. Nutrient deficiencies may occur at ranges above or below the acceptable range (Brechner & Both, 2013).

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Table 4: Nutrient solution consumption and quality of nutrient solution of lettuce 31days after transplanting as affected by different commercially available nutrient solution.

Treatment	Nutrient solution consump-tion plant^{-1} (L)	Total nutrient solution consump-tion (L)	pH					TDS (ppm)				
			0 DAT	7 DAT	14 DAT	21 DAT	31 DAT	0 DAT	7 DAT	14 DAT	21 DAT	31 DAT
BioVoltin	3.45a	27.65a	6.98^{a}	7,01	7.27^{a}	6.66	6.98^{a}	192.75^{c}	138.33	237.67^{bc}	201.67^{b}	216.00^{ab}
Water	2,82b	22.57b	6.92^{a}	6.68	6.88^{ab}	7.2	6.92^{a}	47.83^{d}	29.33	52.67^{c}	50.00^{b}	49.33^{b}
Yamasaki	1.88c	15.02c	6.54^{b}	6.95	6.17^{bc}	6.25	6.78^{a}	539.92^{a}	378	565.33^{ab}	634.00^{ab}	649.00^{a}
Masterblend	1.90c	15.22c	6.52^{b}	6.75	5.84^{c}	6.75	6.73^{a}	571.17	452.33	688.33^{a}	647.00^{ab}	497.00^{ab}
Snap	2.01c	16.11c	6.36^{b}	6.51	6.10^{c}	6.68	6.16^{b}	424.58	516	114.00^{c}	976.67^{a}	405.67^{ab}
NutriHydro	1.71c	13.68c	6.41^{b}	6.54	5.99^{c}	6.38	6.74^{a}	524.5	278	695.67a	577.33^{ab}	547.33^{ab}
Hydroplus	1.78c	14.23c	6.51^{b}	6.58	6.12^{c}	6.54	6.80^{a}	417.75^{b}	313	530.00^{ab}	380.67^{ab}	315.00^{ab}
HSD$_{\alpha 0.05}$	**	**	**	ns	**	ns	**	**	**	**	**	**
CV (%)	7.97	8.01	1.63	3.71	4.01	5.56	2.77	6.43	66.02	30.64	52.07	47.89

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

3.5 Sensory quality attributes and marketability of lettuce

Table 5 shows a highly significant variation was observed on the sensory quality attributes and marketability of lettuce. SNAP was considered best overall which had higher mean values of appearance aroma, crispness, succulence, overall texture, bitterness, overall flavor, overall acceptability, and overall marketability except for color.

Table 5: Sensory quality attributes of lettuce and marketability 31 days after transplanting as affected by different commercially available nutrient solution.

Treatment	Color	Appearance	Aroma	Crispness	Succulence	Overall Texture	Bitterness	Overall Flavor	Overall Acceptability	Marketability
BioVoltin	4.0^{b}	3.34^{a}	3.01^{d}	3.34c	3.68^{c}	3.34^{c}	3.34^{b}	3.01^{c}	1.34^{c}	3.01^{d}
Water	1.03^{d}	1.03^{e}	1.03^{e}	1.03d	1.03^{e}	1.03^{d}	1.03^{e}	1.03^{d}	1.03^{d}	1.03^{e}
Yamasaki	1.02^{d}	1.02^{e}	1.02^{e}	1.02d	1.02^{e}	1.02^{d}	1.02^{e}	1.02^{d}	1.02^{d}	1.02^{e}
Masterblend	1.12^{d}	1.12^{e}	1.12^{e}	1.12d	1.12^{e}	1.12^{d}	1.12^{e}	1.12^{d}	1.12^{d}	1.14^{e}
Snap	4.33^{a}	4.67^{a}	4.67^{a}	4.67a	4.67^{a}	4.67^{a}	3.67^{a}	4.67^{a}	4.67^{a}	5.00^{a}
NutriHydro	3.38^{c}	3.72^{c}	3.38^{c}	3.38c	3.38^{d}	3.38^{c}	1.38^{d}	3.38^{b}	3.38^{b}	3.72^{c}
Hydroplus	4.45^{a}	4.45^{b}	4.45^{b}	4.45b	4.45^{b}	4.45^{b}	2.12^{c}	3.45^{b}	3.45^{b}	4.45^{b}

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$HSD_{\alpha 0.05}$	**	**	**	**	**	**	**	**	**	**
CV (%)	2.49	2.49	2.58	2.53	2.49	2.53	3.52	2.72	2.83	2.57

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, non-significant.

3.6 Cost and Return Analysis of Lettuce

Cost and return analysis of lettuce using different commercially available nutrient solutions is presented in Table 6. Using SNAP solution resulted to higher net return, net profit margin, and return on investment followed by Masterblend, Hydroplus and Yamasaki. The cost of nutrition solution affects the net return of lettuce production as well as the nutrition solution efficiency in terms of the total yield output.

Table 6: Cost and return analysis of lettuce 31 days after transplanting as affected by different commercially available nutrient solution.

Treatment	**Gross Income** (PhP)	**Total Expenses** (PhP)	**Net Return**	**Net Profit Margin**	**Return on Investment** (%)
BioVoltin	0.00[b]	4784.7250	-4784.78[b]	0.0000	-100.00[b]
Water	0.00[b]	4102.7250	-4102.73[b]	0.0000	-100.00[b]
Yamasaki	5599.44[a]	5180.7250	418.71[a]	7.48	8.00[a]
Masterblend	5599.44[a]	4905.7250	693.72[a]	12.39	14.00[a]
Snap	5599.44[a]	4762.7250	836.72[a]	14.94	18.00[a]
NutriHydro	4432.89[a]	5312.7250	-879.84[a]	-47.59	17.00
Hydroplus	5599.44[a]	4971.7250	627.72[a]	11.21	13.00[a]
$HSD_{\alpha 0.05}$	**	ns	**	ns	**
CV (%)	19.92	NaN	-74.35	-15385.20	61.31

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, non-significant.

4. CONCLUSION

This study has shown that hydroponics lettuce production using commercially available nutrient solution is feasible. However, among the different nutrient solution, hydroponics lettuce production using SNAP, Masterblend, Hydroplus, and Yamasaki performed well as it significantly increased yield and is economically viable. Results imply that under favourable conditions, hydroponics lettuce production using commercially available nutrient solution will perform similarly. It is recommended that the same study be conducted during the dry season to verify the performance of lettuce at a different time of the year.

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