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Aquaponic production of lettuce (*Lactuca sativa* L.) with foliar fertilizer supplementation

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Abstract:

Lettuce is popular high value leafy vegetable grown worldwide which contains vitamins and minerals necessary for body metabolism. This study aimed to determine the growth, yield performance and postharvest qualities of lettuce (*Lactuca sativa* L.), investigate the effect of foliar fertilizers on lettuce, and evaluate the cost and return of lettuce production in aggregate aquaponic system. The experiment was conducted in a Randomized Complete Block Design using lettuce as test crop with the following treatments: T1 – no supplementation, T2 – supplemented with effective microorganism (EM), T3 – supplemented with algafer foliar fertilizer, T4 – supplemented with mega yield foliar fertilizer. Lettuce was harvested after 23 days transplanting with 100 percent survival rate and all the harvested plants were marketable. The growth parameters of lettuce were not significantly affected by the experimental treatments except on lettuce supplemented with algafer that produced more number of leaves but has the shortest roots. The free radical scavenging activity and pigment contents of lettuce showed no significant difference in all treatments. Plant tissue analysis of lettuce also indicated no significant difference in terms of percent nitrogen, phosphorous and potassium. The cost and return analysis has indicated lower profit of vegetable production in treatment without foliar fertilizer supplementation but higher net income in algafer supplementation. This revealed that sustainable production of lettuce using an aggregate aquaponic system is inevitable and profitable.

Keywords: aggregate, aquaponics, lettuce, foliar fertilizer, free radical scavenging activity, pigment

1. Introducion

Several technologies in producing quality and safer vegetables have been identified and promoted. With these, aquaponic production of vegetables has been anticipated as a system promoting of low cost production of leafy vegetables with fishes accompaniment. Aquaponic is the combination culture of fish and plants in recirculating systems [8,2] in which nutrients are excreted from the fish and use by the microorganism for breaking down of organic wastes into available form of nutrients and absorbed by plants cultured hydroponically [9]. Since this waste product is toxic to aquatic life when it accumulated in higher concentration, however this harmful effect can be minimized through integration of crops diversification to aquatic life [10]. In this system, the effluent circulates and sustains nutrients, which are needed to the growing crop. Usually, tilapia fish was adapted in aquaporin system because it is tolerant of fluctuating water conditions such as pH, temperature, dissolved oxygen, and dissolved solids [2,3]. In aquaponics system, it is possible to produce a constantly rotating supply of fresh, organic vegetables with minimal effort and expenditure. In addition, better yield performance and postharvest qualities can be attained as well with lettuce and pakchoi production in aggregate hydroponic system using novel nutrient solutions [1]. Most of the crops grown in aquaponic system are leafy and fruit vegetables [4]. Lettuce [7,10,15], basil [8,9] and herbs [3] are grown best in aquaponic system. In addition fruiting plants such as cucumber [12,14,15], tomato [15] and pepper will grow, though aquaponic production of fruit vegetables is not sufficient in supplying all the nutrient requirements needed by the plants for higher production [3]. One of the nutritious leafy vegetables is lettuce, which provides minerals and nutrient that are essential for body metabolism. It contains calories, sodium, carbohydrates, dietary fiber, sugar, protein, vitamin A, vitamin C, and calcium [13] which help body metabolism and cultivated in different ways.

Different technologies have evolved for the production of lettuce. It is an important challenge nowadays to produce safe and quality round year vegetables to sustain the food requirement of a rapidly growing populace. Vegetable industries face difficulty in attaining the optimum requirement for production amidst urbanization. It is very difficult to attain the necessary food requirement with conventional field production due to environmental problems such as heavy rainfall, pest infestation, and climate change. These may lead to the fluctuation of supply and prices of the commodity in the market.

Recently, demand for safe and high quality foods with low cost cultivation and production systems is increasing [6]. This is highly preferred for the sustainability of vegetable production. This study was conducted in order to assess the growth, yield performance, and postharvest qualities of lettuce in aquaponic system supplemented with foliar fertilizers. The study was done at the Vegetable Research Area of the Department of Horticulture, College of Agriculture and Food Science, Visayas State University, Visca, Baybay City, Leyte, Philippines. It aims to determine the growth, yield performance, effect of foliar fertilizers' supplementation, postharvest qualities and the cost and return of lettuce under aggregate aquaponic system.

2. Materials and Methods

Preparation of fish tank

The fish tank was made of plastic barrel with a volume capacity of 150 liters. Three barrels were used and each barrel served as a replication of the study. A rectangular cut was done at the side of the barrel to serve as entrance and discharge of water. The tanks were cleaned properly to get rid of the odor and undesirable particulate matter. Each tank was filled up with 120 L of water prior to the introduction of tilapia (*Oreochromis sp*) fish. Each tank was provided with an aerator to provide oxygen supply for the fish in the aquaculture.

Rearing of fish

Sixty (60) pieces of two-month-old tilapia fish with average weight of 50 grams and length of 6 cm were introduced into each tank. The fishes were feed two times daily with commercial feed grower pellet at a rate of 3-4 grams per tank. The commercial pellet has a guaranteed analysis of crude protein (31%), crude fat (6%), crude fiber (6%), ash (12%) and moisture content (12%).

Storage tank

The storage tank was made of plastic container. The effluent from the fish-rearing tank was manually transferred to the storage tank at 1 week interval. This solution served as fertilizer to the growing plants in beds and discharges into the sump and manually applied back into the vegetable growing beds.

Bed and medium preparation

The bedding material was made of polyvinyl chloride (PVC) pipe material. It is about 1.40 m long and was cut lengthwise along the PVC for about ¼ of the size of the pipes. There were 24 pieces of PVC pipes used in the study. These served as the container of the aggregates composed of fine river sand and coco coir for the plant to grow. The hauled river sand was strained to acquire more or less uniform sizes. The strained sand particles were washed thoroughly with flowing water to eliminate the undesirable salts. On the other hand, coco coir was soaked in water for 1 day and then dried by air. The dried coco coir was sterilized for at least an hour to eliminate harmful microorganism. The mixture was composed of 3 parts fine river sand and 1 part coco coir by volume.

Lettuce seedlings preparation

Lettuce (Romaine variety) vegetable was used in the study. The seeds were secured from the local market distributor of East-West Seed Company. The medium used for the seedling production consisted of garden soil, carbonized rice hull and vermicompost at 1:1:1 ratio. Sterilization of garden soil was done in order to eliminate harmful microorganisms that can cause diseases to the seedlings. The medium was placed in a seedling tray ready for the sowing of seeds. Seeds of the vegetables were sown individually into seedling tray. A starter solution was made by dissolving 1 tablespoon of urea (46-0-0) in a 1 gallon of water. Application was done after the leaves were fully developed. Ten days after sowing, seedlings were hardened for some times to reduce transplanting shock. Watering of the seedlings was done whenever it is necessary.

Transplanting

The hardened seedlings were transplanted into the aggregate in PVC pipes beddings for the aggregate aquaponic system. The beds were 1.40m long and 20 cm in diameter with 7 experimental plants in each bed. Each seedling was planted at a distance of 17 cm between plants and 30 cm between beds. Transplanting was done during afternoon to reduce the stress of the experimental plants.

Experimental design and treatments

The study was arranged in Randomize Complete Block Design with four (4) treatments replicated 3 times. Data gathered were analyzed by using the analysis of variance (ANOVA). Treatment means having significant differences were subjected to Duncan's Multiple Range Test (DMRT). Statistical analysis was carried out using Sirichai Statistics version 6.07. T_1 – Lettuce grown in aggregate aquaponics system. T_2 - Lettuce grown in aggregate aquaponics system enhance with effective microorganism foliar fertilizer. T_3 - Lettuce grown in aggregate aquaponics system supplemented with "Algafer" foliar fertilizer. T_4 - Lettuce grown in aggregate aquaponics system supplemented with inorganic (Mega Yield) foliar fertilizer.

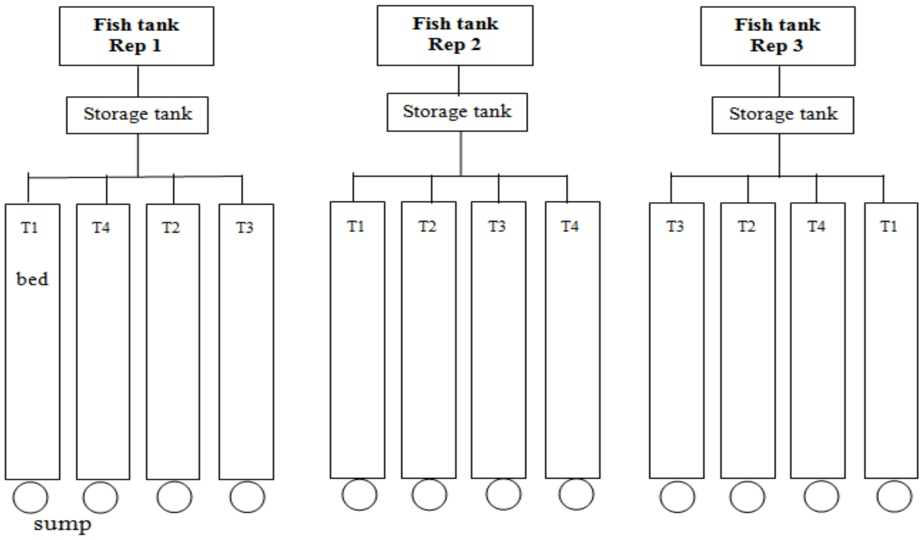

Fig. 1. *Schematic set up of the study*

Protective Structure

The existing protective structure of the Department of Horticulture in the Vegetables Area was used in the study. These were made up of improvised structure using bamboo as the skeleton within its structure with UV plastic roofing materials.

Foliar fertilizer application

"Algafer" is an organic liquid foliar fertilizer derived from marine algae which can enhance plant growth and increase crop yield while "Mega Yield" is an inorganic liquid foliar fertilizer containing essential nutrients needed for plant growth [5]. In addition, "Effective Microorganism (EM)" is a foliar fertilizer formulation containing microbial inoculant. These three foliar fertilizers were used in the study following the recommended concentrations of 1 tablespoon per liter of water for "Algafer", 8 tablespoon per 16 liters water for "Mega Yield", and 2 milliliters per liter of water for "EM". The preparation was based on the manufacturer's instruction as indicated on its label. The application of the foliar fertilizers on lettuce was done every after five days in all experimental set up three (3) days from transplanting.

Foliar Fertilizer Analysis

The analyse of the foliar fertilizers were given by its manufactory. Mega Yield foliar fertilizer has N (4%), P2O5 (7%), K2O (10%), B (2%), Cu (7%), Fe (15%), Mn (5%), Mo (5%), Zn (0.06%) and Cl (0.03). Algafer foliar fertilizer has N (11%), P2O5 (3%) and K2O (4%), trace elements, growth hormones and organic chelates.

Water effluent analysis

The water effluents from the fish tank were collected, submitted and analyzed about total nitrogen, phosphorous, potassium and magnesium at the Central Analytical Services Laboratory of PhilRootcrops, Visayas State University, Baybay City, Leyte.

Water effluent application

The stored water effluent was manually fertigate to the growing beds through a sprinkler. Before the application of nutrient water to growing beds, volume measurement was done in order to determine the total volume of water used for the whole duration of the study. Furthermore, the discharge water in the sump was applied back to the growing beds. The application of this effluent to the plants was done at least a week after storage.

Growth and yield parameters

Days from Transplanting to Harvesting. This was determined by counting the days from transplanting to harvesting.

Weight per Plant (g). This was determined by weighing the individual sample in every replication of the treatment.

Yield per Plot (g). This was determined by weighing all the plants harvested in each plot.

Leaf-Size (cm). This was determined by measuring the length and width of leaves at the time of harvest in individual sample in every replication of the treatment.

Number of Leaves. This was determined by counting the total number of leaves in every sample plant.

Plant Height (cm). This was determined by measuring the height of the plant from above surface of the medium up to the highest part of the plant.

Length of Roots (cm). This was determined by measuring the three longest roots of the sample plants at the time of harvest.

Number of Marketable and Non-marketable Plants. This was determined by counting the marketable plants and non-marketable plants harvested that were free from any damage either caused by insect or mechanical damage.

Weight of Marketable and Non-marketable Plants (g). This was determined by weighing the marketable and non- marketable harvested plants.

Percentage of Survival (%). This was determined by counting the number of dead plants per plot divided by the total number of plants in every plot times 100 as indicated in the formula.

$$\% \text{ survival} = \frac{number\ of\ dead\ plants}{total number\ of\ plants} x\ 100$$

Physico-chemical Properties of Feed Waste Solutions

Feed waste solutions from the fish tanks were collected and sent to the Research Laboratory of the Department of Pure and Applied Chemistry for pH, total dissolved solids (TDS expressed in ppm), oxidation-reduction potential (ORP expressed in mV), and electrical conductivity (EC expressed in µSiemens) tests [11].

Plant Tissue Analysis

Preparation for plant tissue analysis was done at harvest. Plant leaf was prepared, chopped, oven-dried, and submitted for N, P, and K analysis at the Central Analytical Services Laboratory of PhilRootcrops, Visayas State University, Baybay City, Leyte. Total N, P, and K in plant tissue samples were analyzed by using the Kjeldahl, Ultraviolet-visible, and atomic absorption spectrometric methods, respectively.

Determination of Free Radical Scavenging Activity

Samples in every treatment of lettuce was prepared and submitted for free radical scavenging assay at the Department of Pure and Applied Chemistry, College of Arts and Sciences, Visayas State University, Visca, Baybay City, Leyte.

Pigment Analysis of Lettuce

Samples in every treatment of lettuce was prepared and submitted for chlorophyll *a* and *b* and total carotenoids analyses at the Department of Pure and Applied Chemistry of the Visayas State University. The pigments were extracted with 95 % acetone and quantified by UV-vis spectrophotometer.

Cost and Return Analysis

The cost and return of production was determined by recording all the expenses throughout the conduct of the study and income from the crops. Gross incomes were calculated by multiplying the total weight of marketable plants with the prevailing market price of lettuce per kilogram, and do similarly with the tilapia fish. The difference between the gross income and the expenses represented the net income as shown in the formula:

$$\boldsymbol{GI = (WMP\ x\ P) + (YF\ x\ P)}$$

GI – Gross income
WMP – Weight of marketable plants (Kg)
P – Price (PhP)
YF – Yield of fish (Kg)

$$\boldsymbol{NI = (GI - E)}$$

NI – Net income (PhP)
E – Expenses (PhP)

3. Results and Discussion

3.1. Growth and yield parameters

Lettuce was harvested 23 days after transplanting as shown in Table 1. Harvesting time of lettuce was comparable to all treatments. This means that the treatments being employed did not affect the days to harvest of lettuce. From the result of the study, lettuce has 100 percent survival rate, which implies that treatments have no detrimental effect to the growth of lettuce and thus all were found marketable. This means that the foliar supplementation is unnecessary considering the better or the best management of the crop.

Table 2 shows the plant height, root length and number of leaves of lettuce grown in aggregate aquaponic system with foliar fertilizer supplementation. There was no significant difference of plant height of lettuce among treatments. This means that the use of fish feed waste without foliar fertilizer supplementation is sufficient enough to produce lettuce plants with desirable height. This also illustrates the availability of nutrient in fish feed waste available for plant uptake.

The length of roots in lettuce was highly significantly different among treatments. The longest root was observed on plants supplemented with "Mega Yield" foliar fertilizer, but comparable with those lettuce plants that received no supplementation. Lettuce plants supplemented with algafer had the shortest roots. The lettuce plants that received foliar fertilizer supplementation showed greater number of leaves than the lettuce plants without supplementation, which is statistically different. This can perhaps be explained by the contribution of foliar fertilizer application, which contain nutrient elements on lettuce plants. Mega yield foliar fertilizer has N (4%), P2O5 (7%), K2O (10%), B (2%), Cu (7%), Fe (15%), Mn (5%), Mo (5%), Zn (0.06%) and Cl (0.03) and Algafer foliar fertilizer has N (11%), P2O5 (3%) and K2O (4%) necessary for plant growth.

Table 3 shows the leaf size, weight per plant and yield per plot of lettuce grown in aggregate aquaponic system with foliar fertilizer supplementation. No significant difference was found on lettuce plants in terms of leaf size, weight per plant, and yield per plot among treatments. This only shows that growing lettuce in aggregate aquaponic system is sustainable in terms of leaf sizes and yield. In addition, this system is more profitable by removing other expenses such as foliar fertilizer supplementation.

Table 4 shows the marketable weight and free radical scavenging activity of lettuce grown in aggregate aquaponic system with foliar fertilizer supplementation. As it was revealed, no significant difference was observed in lettuce plants in terms of marketable weight and FRSA. This contradicted with the findings of others that free radical scavenging activity is influenced by an enhanced plant biomass from organic fertilization (Personal communication with Dr. Felix M. Salas).

Table 1. *Days from transplanting to harvesting, percent survival and number of marketable plants of lettuce as affected by foliar supplementation in aggregate aquaponic system*

Treatment	Days from Transplanting to Harvesting	% Survival	Number of Marketable Plants
No supplementation	23	100	5
Enhanced with effective microorganism	23	100	5
Supplemented with "Algafer"	23	100	5
Supplemented with "Mega yield"	23	100	5

Table 2. *Plant height, root length and number of leaves of lettuce as affected by foliar supplementation in aggregate aquaponic system*

Treatment	Plant Height (cm)	Root Length (cm)	Number of Leaves
No supplementation	27.30	16.71 ab	18.67 b
Enhanced with effective microorganism	27.83	15.05 bc	19.40 a
Supplemented with "Algafer"	28.61	13.55 c	20.53 a
Supplemented with "Mega yield"	27.25	17.90 a	19.00 a
CV (%)	5.27	6.26	2.79

Means in a column with no letter designation are not significantly different from each other based on 5% level of significance in DMRT

Table 3. *Leaf size, weight per plant and yield per plot of lettuce as affected by foliar supplementation in aggregate aquaponic system*

Treatment	Leaf size (cm)		Weight per plant (g)	Yield per plot (g)
	Length	Width		
No supplementation	20.30	10.78	86.07	430.33
Enhanced with effective microorganism	21.23	11.21	91.53	457.67
Supplemented with "Algafer"	21.06	11.14	97.87	489.33
Supplemented with "Mega yield"	20.47	10.84	89.73	448.67
CV (%)	4.33	4.7	10.72	10.72

Means in a column with no letter designation are not significantly different from each other based on 5% level of significance in DMRT

Table 4. *Marketable weight and free radical scavenging activity of lettuce as affected by foliar supplementation in aggregate aquaponic system*

Treatment	Marketable weight (g)	Free radical scavenging activity (µmol/100g)
No supplementation	430.33	318.50
Enhanced with effective microorganism	457.67	329.04
Supplemented with "Algafer"	489.33	325.31
Supplemented with "Mega yield"	448.67	298.90

CV (%)	10.72	5.49	Mean s in a

column with no letter designation are not significantly different from each other based on 5% level of significance in DMRT

Table 5. *Pigment contents of lettuce as affected by foliar supplementation in aggregate aquaponic system*

Means in a column with no letter designation are not significantly different from each other based on 5% level of significance in DMRT

Treatment	Chlorophyll		Carotenoids (ppm)
	a **(ppm)**	***b*** **(ppm)**	
No supplementation	22.84	29.90	2123.33
Enhanced with effective microorganism	25.58	25.55	2430.00
Supplemented with “Algafer”	25.43	30.87	2293.33
Supplemented with “Mega yield”	24.72	23.76	2403.33
CV (%)	9.24	22.42	12.89

Table 6. *Tissue analysis of lettuce as affected by foliar fertilizer supplementation in aggregate aquaponic system*

Treatment	%Nitrogen	% Phosphorous	% Potassium
No supplementation	4.88	0.05	7.93
Enhanced with effective microorganism	4.68	0.05	8.85
Supplemented with “Algafer”	5.08	0.05	9.00
Supplemented with “Mega yield”	5.11	0.05	10.45
CV (%)	7.02	2.30	6.44

Means in a column with no letter designation are not significantly different from each other based on 5% level of significance in DMRT

Table 7. *Overall expenses and net income (PhP) of growing lettuce as affected by foliar supplementation in aggregate aquaponic system*

Treatment	Yield/sample (g)	Expenses (PhP)	Net income (PhP)
No supplementation	86.07	868.99	1,476.93
Enhanced with effective microorganism	91.53	971.57	1,466.19
Supplemented with “Algafer”	97.87	982.77	1,561.39
Supplemented with “Mega yield”	89.73	973.97	1433.55

Note: 168 plants
Price: lettuce – 100/kg

Table 5 shows the pigment contents of lettuce grown in aggregate aquaponic system with foliar fertilizer supplementation. There was no significant difference between treatments. This means that the pigment development in lettuce plants is not significantly influenced by foliar fertilizer supplementation and the visual quality of lettuce derived from pigmentation is well afforded by aggregate aquaponic system of production. Moreover, this no significant difference of lettuce plants in terms of pigment contents can also be used to explain the result on FRSA of lettuce plants grown in aggregate aquaponic system with foliar fertilizer supplementation.

3.2. Plant Tissue Analysis

Table 6 shows the tissue analysis of lettuce as affected by foliar fertilizer supplementation in aggregate aquaponic system. There was no significant difference between treatments. This means that there was no important contribution of foliar fertilizer with respect to nitrogen, phosphorus, and potassium contents in the tissue of lettuce.

3.3. Cost and Return Analysis

Table 7 shows the overall expenses and net incomes of growing lettuce as affected by foliar fertilizer supplementation in aggregate aquaponic system. Lettuce grown supplemented with foliar fertilizer has higher expenses compared to other treatments. This was due to additional inputs such as effective microorganism and foliar fertilizer, which is considered, added cost in growing lettuce. Lettuce grown without supplementation has lower net income compared to treatment supplemented with algafer. This may be due to the lower weight per plant and lesser number of leaves. With foliar supplementation higher net income was obtained due to production of heavier weight per plant of lettuce. Thus, algafer supplementation has the highest net income. In as much as lesser expenses can be incurred in growing lettuce without supplementation but would still produce comparable yield, then it safe to infer that growing these vegetables in aggregate aquaponic system is potentially adaptable.

4. Conclusion

From the result of the study, the following conclusions were drawn:

1. The growth, yield performance, and postharvest qualities of lettuce grown under aggregate aquaponic system without supplementation were the same as that with foliar fertilizer supplementation.

2. The production of lettuce under aggregate aquaponic system was not affected by organic foliar fertilizer supplementation; and
3. Aggregate aquaponic system is economically viable and has a potential in the production of lettuce in the country because it is cheap, easy to handle, friendly to environment and the net income was just comparable with foliar fertilizer supplementations.

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