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Effect of Aquaculture Wastewater on the Growth of Two Leafy Vegetables (*Celosia argentea* and *Corchorus olitorius*)

*[1]Owodeinde, F.G., [2]Makinde, S.C.O., [1]Ndimele, P.E., [1]Lawal, O.O., [1]Audu, E.F., [1]Fakoya, K.A., and [1]Raimi, A.B.
[1] Department of Fisheries, Faculty of Science, Lagos State University, Ojo, Lagos State, Nigeria.
[2] Department of Botany, Faculty of Science, Lagos State University, Ojo, Lagos State, Nigeria.
*Corresponding Author:
E-mail: fatgbolahanowodeinde@yahoo.com

Abstract

Aquaponics, a bio-integrated system that links aquaculture with agriculture appear to be an excellent way of disposing aquaculture wastewater, saving water, and providing liquid fertilizers to agricultural crops. This study was carried out to evaluate aquaculture wastewater performance on two vegetable (*Celosia argentea* and *Corchorus olitorius*) compared with production using poultry manure. Two treatments were used in the production of the two leafy vegetables between March and May, 2015. Aquaculture waste was manually collected from the culture of *Heteroclarias*, the hybrid of {*Clarias gariepinus* (♀) x *Heterobranchus bidorsalis* (♂) (CG X HB)} and supplied to the crops (Treatment 1). The second group (Treatment 2) was grown using poultry manure which was constantly mixed with tap water before application and the control was grown using only tap water. All plants were grown in silt soil – no nutrient. Growth parameters of the plants were measured at harvest to examine the effects of each treatment. Statistical analysis showed no significant difference ($p>0.05$) in growth rates of *Corchorus olitorius* for both treatments (aquaponics and poultry manure) but a significantly ($p<0.05$) higher growth rate in aquaponics than poultry manure system in *Celosia argentea* production. The study showed that *Celosia argentea* and *Corchorus olitorius* may be grown in an aquaponic system at rates comparable to conventional vegetable (crop) production (using poultry manure), as long as fish stocking densities are high enough.

Keywords: Aquaponics, Leafy vegetables, *Celosia argentea* and *Corchorus olitorius*

Introduction

The world's population is continually growing by approximately 74 million people per year which will ultimately demand that we use more environmentally friendly farming technologies to protect the earth's resources and ecosystems that we depend on for life (Michael and Rachel, 2014). The geometric increase in the world population has also brought about the global increase in demand for food. The sharp increases in food prices that occurred in global and national markets in recent years, and the resulting increases in the number of hungry and malnourished people, have sharpened the awareness of policy-makers and of the general public to the fragility of the global food system. There is global concern about how future generations will produce more food sustainably thus putting pressure on agriculture production. However, agriculture has substantial environmental impact on resources while the conversion of natural land toagriculture; nutrient leaching and the use of chemicals are all serious issues (Tillman *et al.*, 2002).

Aquaculture is a subsector in food production. However, the intensive practice of aquaculture generates substantial amount of effluent, containing uneaten feed and feces. It is essential that nutrients from aquaculture wastewater should be removed in order to protect receiving water from eutrophication and for potential reuse of the treated water. The integration of aquaculture with agriculture appears to be an excellent way of saving water, disposing aquaculture wastewater and providing fertilizer to the crop (Read and Fernandes, 2003; Endut *et al*., 2011). Aquaculture in Nigeria consists largely of intensive and semi-intensive culture systems where water quality is largely maintained within acceptable limits through frequent water exchanges. This fish farming practices requires access to plenty of good quality water from bore-holes, streams and rivers. The discharge of untreated aquaculture wastewater contaminates the environment and the receiving water bodies, spreading infections that cause disease outbreaks. There is urgent need for remediation of aquaculture wastewater through aquaponics which is a bio-integrated food production system. Lucas and Southgate (2003) opined that whilst the majority of the discharged compounds from aquaculture are not lethal, it is beneficial to keep levels low as the effects on human health of eating fish and vegetables in nutrient laden water are not entirely understood.

Adler *et al*., (2000) stressed the importance of remediation of aquaculture wastewater most especially in many areas of the world where water is a limited resource. Aquaponics, known as the integration of hydroponics with aquaculture is gaining increased attention as a bio-integrated food production system. Here nutrient rich effluent from fish tanks is used to fertigate plant production beds (Endut *et al*, (2011). The primary goal of aquaponics is to reuse the nutrients released by fish to grow crop plants. This integrated culture systems promote nutrient recycling and aquaculture-agriculture yields so they are more environmentally sustainable than most traditional farming practices which have resulted in wide spread of soil erosion, desertification and pollution in Asia and Africa. (Bakhsh, 2008).

Aquaponics system has been examined over the past decades with a wide variety of system designs, plant and animal species and experimental protocols efficiencies (Endut *et al.,* 2011). It is just like a natural ecosystem combining plants, soil, bacteria, substrates and fish wastewater to enhance physical, chemical and bacteriological procedures that are naturally available in the root zone of the plants. Results emanating from this showed efficient use of resources, reduction in the risk of total crop failure, additional sources of food, extra income and reduction of operational cost for farmers than fish culture alone (Rakocy *et al*, 2006; Snow and Ghaly, 2008 and Endut *et al*, 2011).

In Nigeria, most of the vegetable plant growers use poultry manure and little or no inorganic fertilizers in growing their vegetables (Olaniyan *et al*., 2006). However, with the growing trend of diseases emanating from the poultry, it is imperative for the vegetable plant growers to look for alternative ways of fertilizing the production beds of the vegetables in order to prevent the spread of diseases from the poultry (Lucas and Lawani, 1985). The objectives of this research was to find out if aquaculture wastewater taken from the culture of *Heteroclarias,* the hybrid of (*Clarias gariepinus* (♀) x *Heterobranchus bidorsalis* (♂) (CG X HB) contained enough nutrients to sustain plant growth and to compare growth rates of both vegetables (*Corchorus olitorius* and *Celosia argentea*) grown using poultry manure.

Materials and Methods

This study was carried out in the concrete tanks outside the Fish Hatchery Complex of the Department of Fisheries, Lagos State University, Ojo, Lagos State, Nigeria with the dimension 4m long by 1.5m wide and 1m deep, and in the Green House in the Botanical garden (plant culture) of Lagos State University between 10th of March to 15th of May, 2015.

Experimental Procedure

Collection of Experimental Fish

A total of 750 fingerling of the hybrid of *Clarias gariepinus* (♀) X *Heterobranchus bidorsalis* (♂)[*Heteroclarias*] (mean weight 7.5 ± 1.5g) used to generate the aquaculture waste in this study were obtained from the Hatchery Complex of the Department of Fisheries, Lagos State University, Lagos State, Nigeria. The fish were hand fed two times daily, with floating pellet of compounded feed containing 45% crude protein prepared by using the following ingredients; fish meal (15.8%), soybean meal (59.4%), yellow maize (18.2%) , blood meal (5.1%) vegetable oil (1.0%), and vitamin premix (0.5%) at 3% of their body weight based on the recommendation of Viveen *et. al*, (1986). The feed size was adjusted to compensate for changes in the fish size as the fish grows. The amount of food dispensed (kg) to the fish stocked in the experimental tank were adjusted bi-weekly by sub-sampling the population of the fish species in order to reflect the fortnightly increase in biomass using the following:

$$W_1 = W_o + (Wo \times F/C) \qquad \text{(Stickney, 1979).}$$

Where W_1 is the weight of the fish at day 1, Wo is the weight of the fish at day zero, F is the percentage feeding rate and C is the food conversion ratio (FCR).

FCR = Feed fed / Weight gain

Plant Culture

The *Corchorus olitorius L.* (Common names: Jew's Mallow, Wild jute,) seedlings were directly sown in plastic bowls, two seeds per hole evenly spaced at 3-5cm apart. Seeds of *Celosia argentea* L. (Common names plumed cockscomb, spinach) were sown in plastic bowls, two seeds per hole with evenly spaced at 5-6 cm apart (Ilodibia *et al*., 2016; Nyadanu *et al*., 2016).

Treatments

Bowls 1 – 5 were filled with silt (media) which contain no nutrient. The *Corchorus olitorius* seedlings were directly sown in the media. The plants were watered manually two times daily with aquaculture wastewater at 08.00 am and 16.00 pm.

Bowls 6 and 7 were filled with silt (media) mixed with poultry manure. *Corchorus olitorius* seedlings were directly sown in the media with poultry manure. The plants were watered manually two times daily with ordinary tap water at 08.00 am and 16.00 pm.

Control of Treatment 1

Bowls 8 and 9 (which served as the control for the first treatment) were filled with silt (media) with no nutrient. *Corchorus olitorius* plants were planted in the media using the method described above. The plants were watered manually two times daily with ordinary tap water at 08.00 am and 16.00 pm.

Bowls 10 – 14 were filled with silt [media] which contain no nutrient. *Celosia argentia* seeds commonly called spinach were sown in plastic bowls, two seeds per hole with evenly spaced at 5-6 cm apart. The plants were watered manually two times daily with aquaculture wastewater at 08.00 am and 16.00 pm.

Bowls 15 and 16 were filled with silt [media] with poultry manure *Celosia argentea* seeds commonly called spinach were sown in plastic bowls, two seeds per hole with evenly spaced at 5-6 cm apart. The plants were watered manually two times daily with ordinary tap water at 08.00 am and 16.00 pm.

Control of Treatment 2

Bowls 17 and 18 (which serve as the control for the second treatment) were filled with silt (media) with no nutrient. *Celosia argentea* plants were planted in the media using the method described above. The plants were watered manually two times daily with ordinary tap water at 08.00 am and 16.00 pm.

Nutrient Supply

Jute plant (*Corchorus olitorius*) in bowls 1 – 5 and Spinach (*Celosia argentea*) in bowls 10 – 15 were supplied with aquaculture wastewater manually by first draining the fish wastewater into two 15 liter buckets and taking into the green house in the Botanical Garden of Lagos State University. The plant species (*Corchorus olitorius* and *Celosia argentea*) were supplied with aquaculture wastewater twice daily 08.00 am and 16.00 pm.

Monitoring and data collection

The key variables of concern in this study are plants growth and yield as well as water quality parameters of the culturing tank. During the germination period, seeds germination and seedlings height (parameters) were observed and recorded daily. However, the following parameters were measured at harvest; plant fresh weight (g); plant dry weight (g), plant height (cm), no. of leaves, total leaf length (cm), leaf blade length (cm), petiole length (cm), leaf width (cm) and stem Girth (cm).

Assessment of water quality parameters

Water quality data monitored during the study period included temperature, dissolved oxygen, pH, and total ammonia-nitrogen. Temperature was monitored with a simple mercury–in-glass thermometer graduated in 0.01°C. Dissolved oxygen was normally measured between 0700-0800 hours using Lutron Dissolved Oxygen Meter - DO-5509 and further authenticated by alkaline-azide – modification of Winkler's method (Boyd, 1981). pH values were determined using a Jenway PHS-25 pH meter, while total ammonia-nitrogen were determined by the standard methods as described by Boyd (1981).

Data Analyses

Growth performances of the two vegetable species (*Corchorus olitorius* and *Celosia argentea*) were determined and expressed as mean ± standard deviation. Data analyses were performed using statistical package for the social sciences (SPSS), Version 16 with level of significance set at 0.05 (significance at $P < 0.05$). Mean values of plant growth rate, plant yield between treatments were tested with two-way ANOVA. If there were significant difference at 0.05, then Duncan multiple comparison test was used to compare means in order to identify significant difference between treatments.

Results

Water Quality Parameters

The pH ranged between 6.8 and 7.9 with a mean of 7.3±0.17. Temperature ranged between 25 and 27°C with a mean value of 26±0.28. Dissolved oxygen ranged between 6.5 and 7.6 mg/l with a mean value of 7.0±0.17 mg/L, Dissolved Carbon-dioxide ranged between 6 and 9.0 mg/L, mean value of 7.16 ± 0.48. Total ammonia-nitrogen ranged between 0.01 and 0.04 mg/L, with mean value of 0.025 ± 0.004. Calcium hardness ranged between 20mg/L and 25mg/L with mean value of 22.5 ± 0.25.

Plant Growth

After 3 and 4 days, the radicles of *Celosia argentea* and *Corchorus olitorius* had broken through the seed coats respectively and were visible on 80-85% of the seeds. During germination periods, the plant seedlings in all growing bowls grew rapidly and fairly uniform and appeared healthy and green in colour. At the end of the germination periods, the spinach (*Celosia argentea)* and Jew Meadow (*Corchorus olitorius*) were approximately 52cm and 36cm in height for both vegetables respectively. All the vegetables in all the bowls (replicates) grew quickly and seemed healthy with no signs of any nutrient deficiency syndromes or toxic effect during the growth periods. At the end of the growth period, the spinach (*Celosia argentea*) and Jew Meadow (*Corchorus olitorius*) plants reached market size of 45 – 50 cm and 30 – 35 cm respectively. The results of plant growth in terms of plant height for both crops are shown in Table 1 and Figures 1 and 2.

Number of Leaves:

The number of leaves for *Celosia argentea* gave a mean and standard deviation value of 80.6±12.70 for aquaculture wastewater treatment with minimum and maximum value of 99 and 65, 62.5±4.95 for poultry manure treatment minimum and maximum value of 66 and 59 and 21.5±4.95 for control minimum and maximum value of 25 and 18. However, there was no significant difference between the number on leaves of the aquaculture wastewater treatment and poultry manure treatment, however, both showed significant differences from that of the control (Table 1).

Table 1: Growth parameters (mean±SD) of spinach (*Celosia argentea)*

Characteristics	Treatments		
	Aquaculture wastewater (Treatment 1)	Poultry Manure (Treatment 2)	Ordinary water (Control)
No. of Leaves	80.6±12.70[a]	62.5±4.95[a]	21.5±4.95[b]
Leaf Width	5.08±0.54[a]	3.64±1.07[b]	0.68±0.23[c]
Total Leaf Length	12.06±1.66[a]	9.26±1.21[b]	1.96±0.16[c]
Leaf Blade Length	9.10±1.18[a]	6.98±0.66[b]	1.70±0.27[c]
Petiole Length	2.96±0.55[a]	2.28±0.69[a]	0.36±0.27[b]
Plant Height	33.36±5.84[a]	25.39±6.29[a]	8.15±0.65[b]
Stem Girth	3.32±0.40[a]	2.56±0.42[b]	1.23±0.44[c]
Wet Weight	22.68±10.16[a]	10.53±7.28[ab]	2.76±1.07[b]
Dry Weight	7.03±3.56[a]	1.42±1.17[ab]	0.79±0.56[b]

[a, b, c] **Values showing the same letter are not significantly different from each other (P=0.05, DMR)**

Number of leaves for *Corchorusolitorius* gave a mean and standard deviation value of 66.20±9.98 for aquaculture wastewater treatment with minimum and maximum value of 69 and 51, 85.5±13.44for poultry manure treatment minimum and maximum value of 95 and 76 and 20.00±1.44for control minimum and maximum value of 21 and 19. However, there was no significant difference between the number on leaves of the aquaculture wastewater treatment and poultry manure treatment, but both showed significant differences from that of the control (Table2).

Table 2: Growth parameters (mean±SD) of Jew Meadow *(Corchorus olitorius)*

Characteristics	Treatments		
	Aquaculture wastewater (Treatment 1)	Poultry Manure (Treatment 2)	Ordinary water (Control)
No. of Leaves	66.20±9.98[a]	85.5±13.44[a]	20.00±1.41[b]
Leaf Width	8.38±2.09[a]	7.78±1.69[a]	1.38±0.37[b]
Total Leaf Length	13.42±2.97[a]	11.84±1.71[a]	2.00±0.19[b]
Leaf Blade Length	9.82±2.42[a]	7.84±1.03[a]	1.54±0.42[b]
Petiole Length	3.60±1.36[a]	4.00±0.74[a]	0.50±0.35[b]
Plant Height	40.66±13.23[a]	48.15±14.09[a]	10.86±1.51[b]
Stem Girth	2.56±0.60[a]	2.60±0.58[a]	1.01±0.19[b]
Wet Weight	12.76±9.87[a]	11.19±6.70[a]	1.25±0.32[b]
Dry Weight	2.67±2.33[a]	1.96±1.23[a]	0.74±0.33[a]

[a, b] **Values showing the same letter are not significantly different from each other (P=0.05, DMR)**

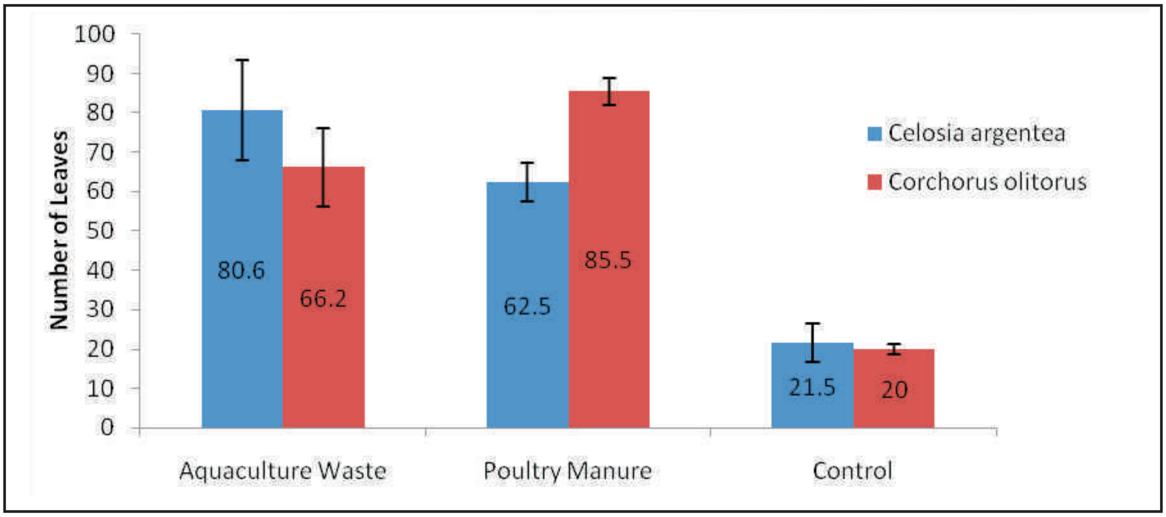

Figure 1: The Effect of Aquaculture Wastewater and Poultry Manure on Number of Leaves per Plant in two Leafy Vegetables

The Leaf width for *Celosia argentea* gave a mean and standard deviation value of 5.08±0.54 for aquaculture wastewater treatment with minimum and maximum value of 5.7 and 4.4, 3.64±1.07 for poultry manure treatment minimum and maximum value of 4.7 and 2.2 and 1.38±0.37 for control minimum and maximum value of 0.9 and 0.4. However, there was no significant difference between all three groups (Table 1).

The Leaf width for *Corchorus olitorius* gave a mean and standard deviation value of 8.38±2.09 for aquaculture wastewater treatment with minimum and maximum value of 11.6 and 5.9, 7.78±1.69 for poultry manure treatment minimum and maximum value of 9.0 and 5.2 and 1.38±0.37 for control minimum and maximum value of 1.8 and 0.9. However, there was no significant difference between the number of leaves of the aquaculture wastewater treatment and poultry manure treatment, but both showed significant differences from that of the control (Table 2 and Figure 2).

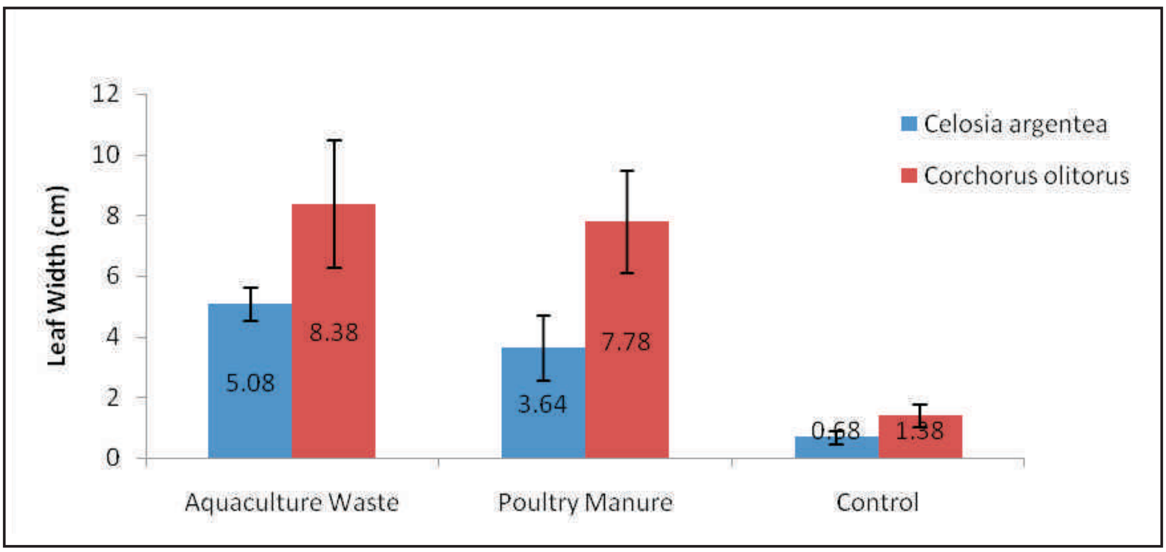

Figure 2: The Effect of Aquaculture Wastewater and Poultry Manure on the Leaf width per Plant in two Leafy Vegetables

The Total petiole leaf length for *Celosia argentea* also showed no significant difference between all three treatments. Aquaculture wastewater treatment gave a mean and standard deviation value of 12.06±1.66 with minimum and maximum value of 14.7 and 10.3, poultry manure treatment gave a mean and standard deviation value of 9.26±1.21 with minimum and maximum value of 10.4 and 8.0 and 1.96±0.16 for control minimum and maximum value of 2.2 and 1.8.

However, there was no significant difference between all three groups (Table 1 and Figure 3).

The Total petiole leaf length for *Corchorus olitorius* also showed significant difference between aquaculture wastewater treatment and poultry manure treatment but not with the control. Aquaculture wastewater treatment gave a mean and standard deviation value of 13.42±2.97; poultry manure treatment gave a mean and standard deviation value of 9.26±1.21 and 1.96±0.16 for control (Table 2 and Figure 4).

The leaf blade length of *Celosia argentea* showed significant difference between all three treatments. The mean and standard deviation

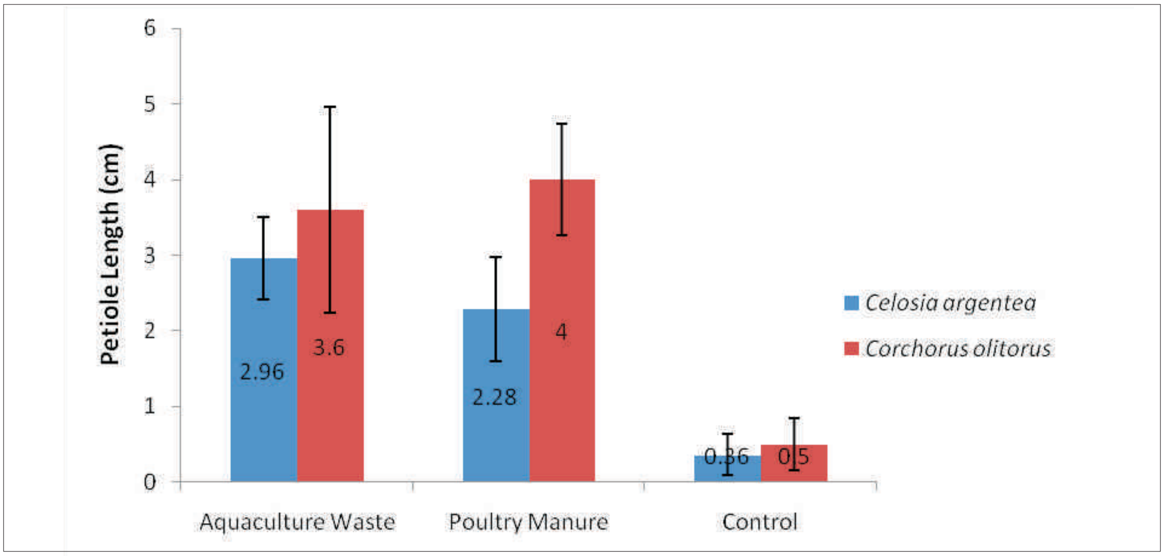

Figure 3: The Effect of Aquaculture Wastewater and Poultry Manure on the Petiole Leave Length per Plant in two Leafy Vegetables

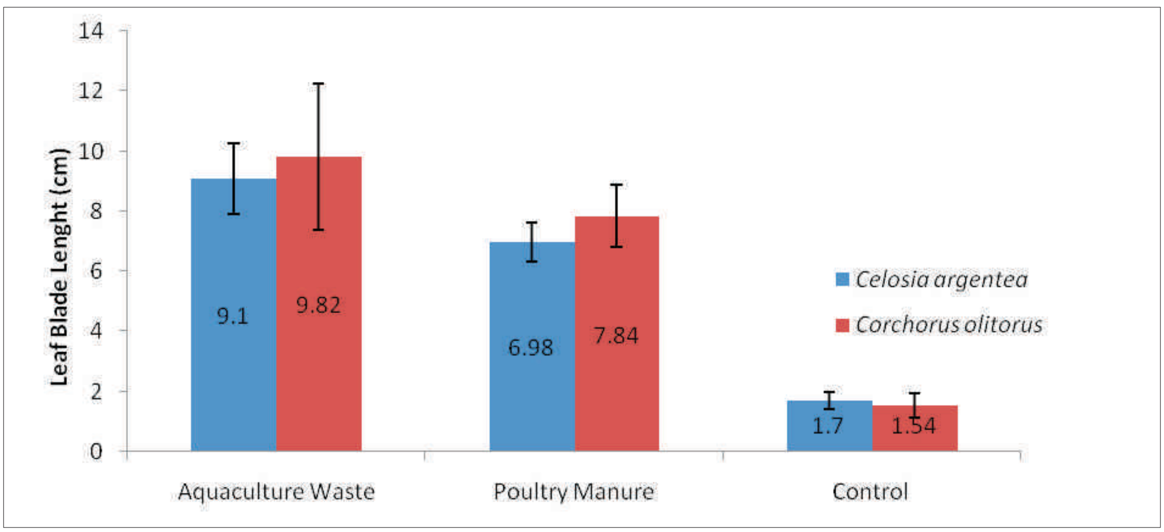

Figure 4: The Effect of Aquaculture Wastewater and Poultry Manure on the leaf blade Length per Plant in two Leafy Vegetables

values of aquaculture wastewater treatment, poultry manure treatment and controls are 9.10±1.18, 6.98±0.66 and 1.70±0.27 respectively (Table 1 and Figure 4).

However the leaf blade length of *Corchorus olitorius* showed no significant difference between the aquaculture wastewater treatment, 9.82±2.42 and poultry manure, 7.84±1.03. The control showed significant difference with the treatment groups, 1.54±0.42 (Table 2 and Figure 4).

Plant height of *Celosia argentea* for aquaculture wastewater treatment and poultry manure treatment showed no significance

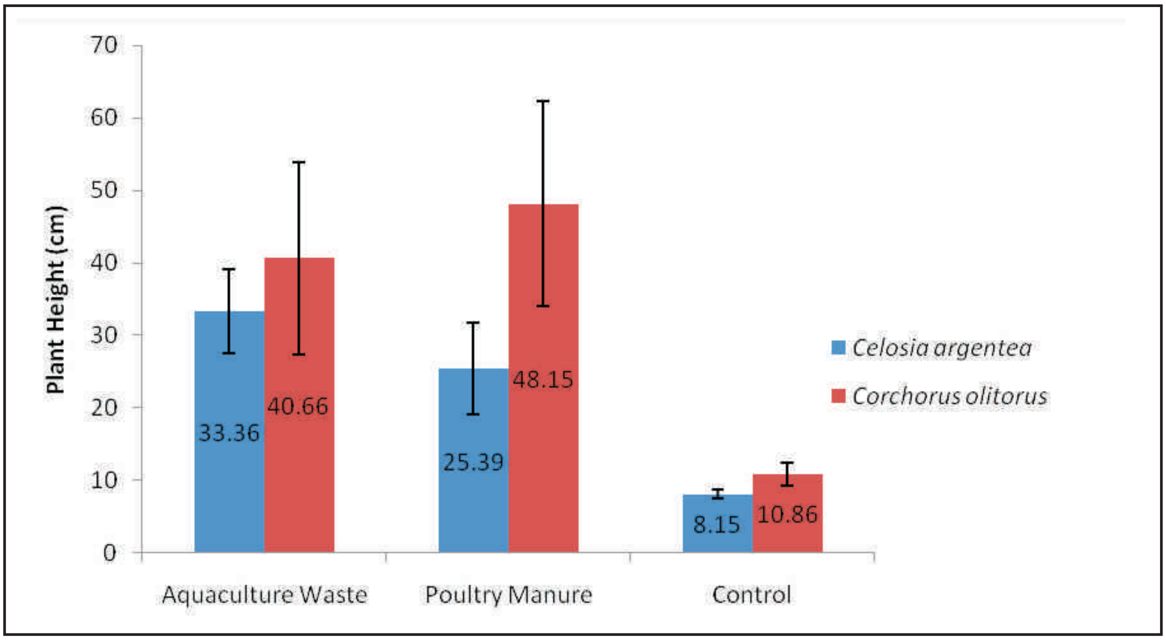

Figure 5: The Effect of Aquaculture Wastewater and Poultry Manure on the Plant Height per Plant in two Leafy Vegetables

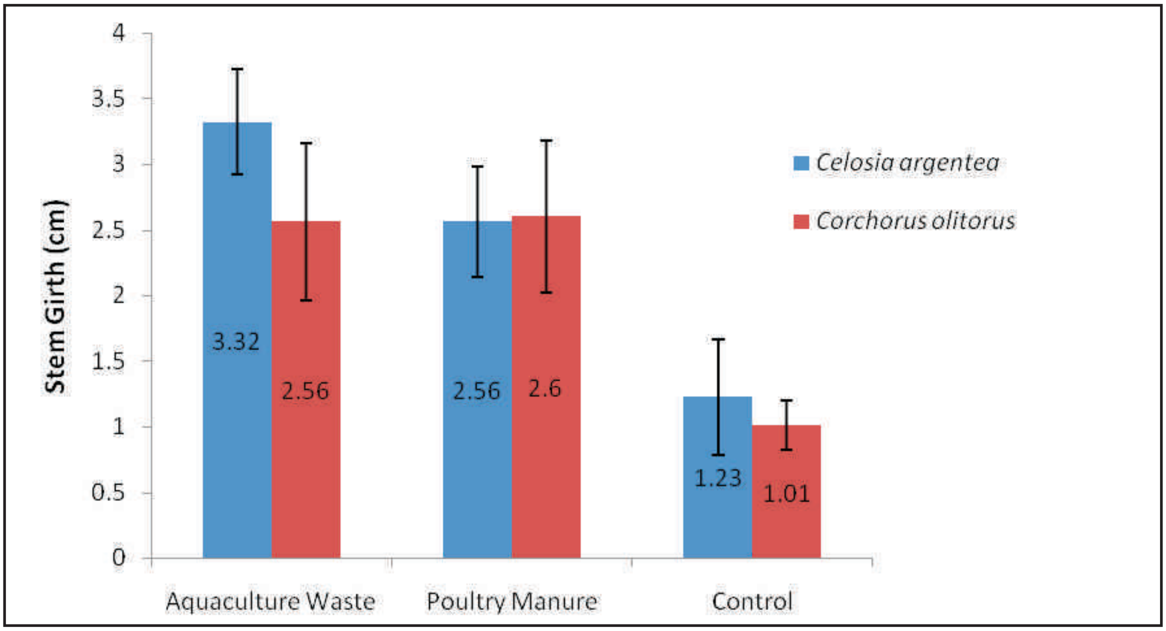

Figure 6: The Effect of Aquaculture Wastewater and Poultry Manure on the Stem girth per Plant in two Leafy Vegetables

difference but both showed significant difference from that of the control with mean and standard deviation values of 33.36±5.84, 25.39±6.29 and 8.15±0.65 respectively. (Table 1 and Figure 5).

Corchorus olitorius similarly, showed no significant difference between the plant height of aquaculture wastewater treatment and poultry manure treatment, 40.66±13.23 and 48.15±14.09 respectively. Both showed significant differences from that of the control, 10.86±1.51 (Table 2 and figure 5).

The stem girth of *Celosia argentea* showed significant difference between the three groups, with mean and standard deviation values of aquaculture wastewater, poultry manure treatment and control of 3.32±0.40, 2.56±0.42 and 1.23±0.44 respectively (Table 1 and Figure 6).

Corchorus olitorius however showed no significant difference between the aquaculture wastewater treatment 2.56±0.60 and poultry manure treatment 2.60±0.58. However, both showed significant differences from that of the control 1.01±0.19 (Table 2 and Figure 6).

There were no significant differences in the wet weight and dry weight values of *Celosia argentea* and that of aquaculture wastewater and poultry manure treatments and no significant difference between the poultry manure treatment and control. However, there was a significant difference between aquaculture wastewater treatment and the control experiment (Tables 1& 2 and Figures 7& 8).

Also, there were no significant differences between the wet and dry weight values of aquaculture wastewater treatment and poultry treatment in *Corchorus olitorius*, however, both showed significant differences from that of the control (Tables 1&2 and Figure 7& 8).

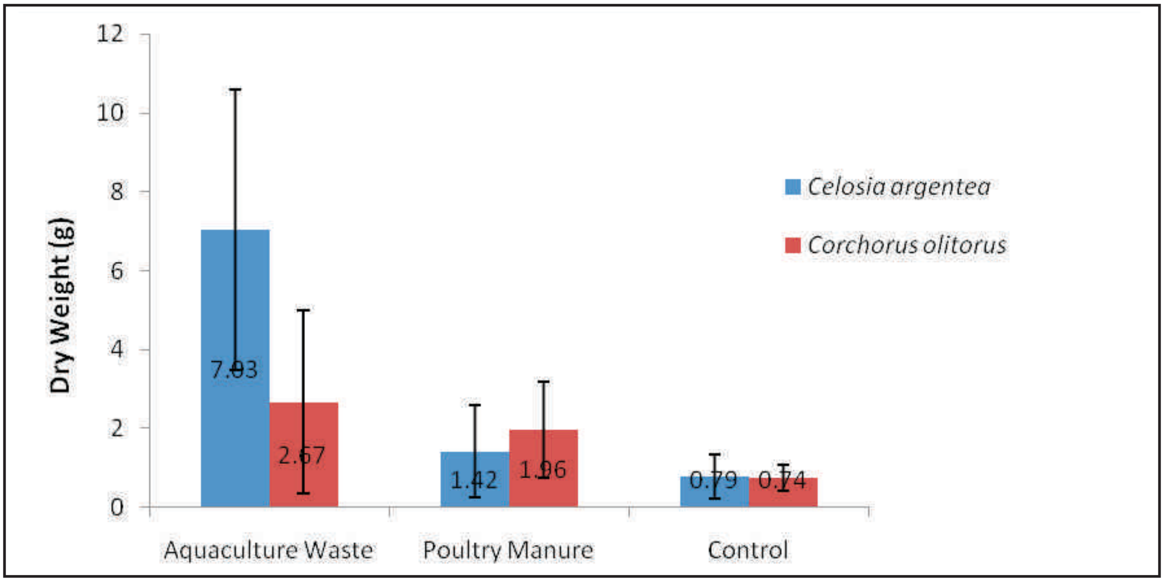

Figure 7: The Effect of Aquaculture Wastewater and Poultry Manure on the Dry Weight per Plant in two Leafy Vegetables

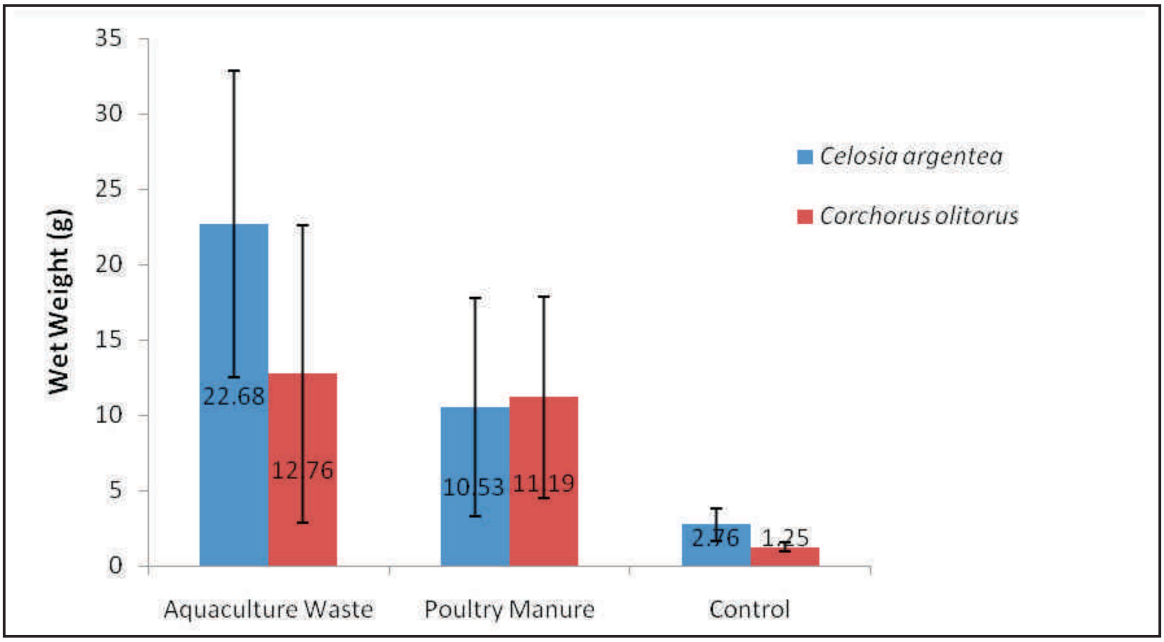

Figure 8: The Effect of Aquaculture Wastewater and Poultry Manure on the Wet weight per Plant in two Leafy Vegetables

Coefficient of variations of *Celosia argentea* and *Corchorus olitorius* respectively were shown in Tables 3 and 4. However, Table 3 shows low variability between the values of all three treatments of *Celosia argentea* except for the wet weight and dry weight values which appears to be high (above 35%). Table 4 also shows the variability between the values of *Corchorus olitorius* which appears to be low except for the petiole length of aquaculture waste treatment and the control. Also the wet weight showed a high variability between the values of aquaculture wastewater treatment and poultry manure treatment but was low for the control. The dry weight values for all three treatments showed a high variability (Table 4).

Table 3: Coefficient of variation for *Celosia argentea across different treatments*

Characteristics	Treatments		
	Aquaculture wastewater (Treatment 1)	**Poultry Manure (Treatment 2)**	**Ordinary water (Control)**
No. of Leaves	16	8	23
Leaf Width	11	29	34
Total Leaf Length	14	13	8
Leaf Blade Length	13	9	16
Petiole Length	19	30	75
Plant Height	18	25	8
Stem Girth	12	16	36
Wet Weight	45	69	39
Dry Weight	51	82	71

Table 4: Coefficient of variation for Corchorus *olitorius across different treatments*

Characteristics	Treatments		
	Aquaculture wastewater (Treatment 1)	**Poultry Manure (Treatment 2)**	**Ordinary water (Control)**
No. of Leaves	15	4	7
Leaf Width	25	22	27
Total Leaf Length	22	14	10
Leaf Blade Length	25	13	27
Petiole Length	38	19	70
Plant Height	33	29	14
Stem Girth	23	22	19
Wet Weig ht	83	60	26
Dry Weight	87	63	45

Discussion

During the experimental periods, it was possible to recognize distinct differences between the treatments in the two leafy vegetables (*Corchorus olitorius* and *Celosia argentea*) and the control. While *Celosia argentea* grown in aquaculture wastewater showed significantly ($p<0.05$) higher growth variables than those grown in poultry manure, *Corchorus olitorius* did not. The quantitative and qualitative measurements for aquaculture wastewater leafy vegetables showed significant improvement over the poultry manure treatment especially for *Celosia argentea*. Number of leaves, leaf width, total leaf length, leaf blade length, plant height, stem girth, wet weight and dry weight were significantly higher in vegetables grown in aquaculture wastewater than those grown in poultry manure and ordinary water. Lennard and Ward (2019) reported that aquaponic method either equalled or was better than the standard hydroponic methods for plant growth (production) of lettuce and herbs, and was also better than the hydroponic method in the saleable plant quality of the herbs. A study by Savidov (2005) compared plant growth rates (shoot height, weight) in an aquaponically-derived nutrient solution to a hydroponic solution for several crop species {cucumber (*Cucumis sativus* L.), tomato (*Solanum lycopersicon* L.), basil (*Ocimum basilicum* L.), rosemary (*Rosmarinus officinalis* L.), and *Echinacea* spp.), and demonstrated that in many of the comparisons, the aquaponic nutrient produced equal or greater shoot weights (leaf weights) when compared to the hydroponic solution. Plants are able to grow in soil-less or silt media system where mineral concentrations are low, as long as the nutrients can be replenished at a level comparable to their uptake (Salisbury and Ross, 1992). The continual renewal of aquaculture wastewater to the two leafy vegetables resulted in a tremendous growth observed in the vegetables treated with aquaculture wastewater compared with the poultry manure treatment.

The amount of solid particles present in the aquaculture wastewater is linked with the amount of dissolved oxygen concentration in the systems because the aerobic breakdown of excreta and uneaten food increases the amount of dissolved oxygen removed from the water. It is therefore important to note that mechanical aeration of intensively stocked fish must be undertaken because oxygen is needed in the breakdown of ammonia to nitrite and finally nitrite to nitrate. Nitrification is the main process that transforms $NH4^{+}$ to NO^{3-} in the presence of oxygen (Hu *et al*., 2015). Total ammonia nitrogen (TAN) is oxidized into nitrite (NO^{2-}) by ammonia oxidizing bacteria (AOB) (e.g., *Nitrosomonas*, *Nitrosococcus*, *Nitrosospira*, *Nitrosolobus*, *Nitrosovibrio* sp., etc.) and ammonia oxidizing archaea (AOA). The resulting NO^{2-} is oxidized to NO^{3-} (nitrate) by nitrite oxidizing bacteria (NOB) (e.g., *Nitrobacter*, *Nitrococcus*, *Nitrospira*, *Nitrospina* sp., etc.) (Ebeling *et al*., 2006; Gerardi, 2002; Panuvatvanich *et al*., 2009). Ammonia oxidizing archaea do not appear to play a role in aquaponic systems although their abundance was reported in similar environment such as soils and oceans (Jung *et al*., 2014; Xia *et al*., 2011; Zhang *et al*., 2012). Ammonia oxidizing archaea is responsible for oxidizing ammonia under extremely low NH^{4+} concentrations (about 2 g N/L) due to their physiological diversity, leading to toleration and adaptation to extreme nutrient limitations (Martens-Habbena *et al*., 2009). The nitrification rate of AOA will not be significantly higher than that of AOB in nitrogen-rich environments, such as aquaponic systems. Thus, nitrification by AOA does not significantly occur in aquaponic systems (Hu *et al*., 2015; Zou *et al*., 2016). In aquaponic systems, TAN needs to be oxidized to NO^{3-} because NO^{3-} is not toxic to fish even at high concentrations of up to 150–300 mg N/L (Graber and Junge, 2009; Hu *et al*., 2014). However, TAN and NO^{2-} concentrations have to be maintained at low levels (Buzby and Lin, 2014; Liang and Chien, 2013). For example, TAN and NO^{2-} concentrations of 1.6–2.9 mg N/L and 0.4–1.1 mg N/L, respectively, were observed in well-operated aquaponic systems using tilapia and basil, while NO^{3-} accumulated at relatively high concentrations of up to 54.7 mg N/L (Rakocy *et al*., 2003). Studies showed that the NO^{3-} in aquaponic systems can vary from 10 mg N/L to over 200 mg N/L without stress to tilapia and plants (Lam *et al*., 2015).

The growth observed in the leafy vegetables (*Corchorus olitorius* and *Celosia argentea*) treated with tap water simply acknowledged the role of water in plant growth, which indicates that water contains nutrients such as nitrogen and are extremely important in plant growth. Johnson, (2007) stated that nitrogen is an essential nutrient for plant growth, where a deficiency of it, can stunt a plants growth.The result thus tallied with the result of research work by Bouchard *et al* (2007).The lesser vegetative parameters observed in the plants irrigated with tap water compared to those irrigated with aquaculture effluent and poultry manure were probably attributable to the lower availability of nutrients, which may have negatively affected cell enlargement (Boyer, 1988).

Conclusion

Aquaculture wastewater treatments in this experiment produced higher crop yield compared to the poultry manure treatment. It is worth considering the incorporation of the aquaponic system into the agricultural system of developing country like Nigeria bearing in mind the advantages of producing two saleable products; fish and vegetables. Nigeria should enhance her status in integrated agriculture-aquaculture systems (IAA) – which is the flow of nutrients between enterprises i.e. wastes from one enterprise become inputs in another to increase production as being practiced in Asia. It is our belief that considerable potential exists for further aquaculture integrations in Nigeria that will improve the livelihood of rural small-scale fish farmers.

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References

Adler, P. R; Harper, J. K; Takeda, F; Wade, E. F; and Summer-felt, S. T. (2000). Economic evaluation of hydroponics and other treatment options for phosphorus removal in aquaculture effluent. Horticulture Science, 35 [993-999].

Anonymous. (2007). The use aquaculture wastewater to produce lettuce plant in soilless culture. Submitted in partial fulfilment of the requirements for the degree of B.Sc. Horticulture. Anonymised University. pp 68.

Bakhsh, K. (2008). Integrated Culture, Hydroponics and Aquaponics System. University of Malaysia Terengganu, Kuala Terengganu, Malaysia.

Bouchard, N; Harmon, K; Markham, H and Vandefifer, S. (2007). Effects of Various Types of Water on the Growth of Radishes [*Raphanussativus*]. Ecology Laboratory Manual, Michigan State University. Pages: 1-24.

Boyd, C.E. (1981). *Water quality in Warmwater Fish Ponds*. Auburn University Agricultural Experiment Station Alabama. 359pp.

Boyer, J.S., (1988). Cell enlargement and growth induced water potentials. *Plant Physiology*, 7: 311–316.

Buzby, K.M. and Lin, L.-S. (2014). Scaling aquaponic systems: balancing plant uptake with fish output. *Aquac. Eng.*, 63: 39–44.

Ebeling, J.M., Timmons, M.B., Bisogni, J.J. (2006). Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. *Aquaculture,* 257: 346–358.

Endut A., N. Jusoh, W.B. Ali, Nik Wan and A. Hassan, (2009). Effect of flow rate on water quality parameters and plant growth of water spinach (*Ipomoea aquatica*) in an aquaponic recirculation system, Desal.Wat.Treat., 5: 19-282.

Endut, A., Jusoh, A., Ali, N., and Wan Nik, W. B. (2011). Nutrient removal from aquaculture wastewater by vegetable production in aquaponics recirculation system. *Desalination and Water Treatment* 32: 422-430.

Gerardi, M.H. (2002). Nitrification and Denitrification in the Activated Sludge Process. John Wiley and Sons, Inc, New York.

Ghaly, A. E. and Alkoaik, F. N. (2010). Effect of Municipal Solid Waste Compost on the Growth and Production of Vegetable Crops. *American Journal of Agricultural and Biological Science* 5 [3]: 274-281.

Graber, A., Junge, R. (2009). Aquaponic Systems: nutrient recycling from fish wastewater by vegetable production. *Desalination*, 246: 147–156.

Hu, Z., Lee, J.W., Chandran, K., Kim, S., Sharma, K., Khanal, S.K. (2014). Influence of carbohydrate addition on nitrogen transformations and greenhouse gas emissions of intensive aquaculture system. *Sci. Total Environ.* 470–471: 193–200.

Hu, Z., Lee, J.W., Chandran, K., Kim, S., Brotto, A.C., Khanal, S.K., (2015). Effect of plant species on nitrogen recovery in aquaponics. *Bioresour. Technol*., 188: 92–98.

Jung, M.-Y., Well, R., Min, D., Giesemann, A., Park, S.-J., Kim, J.-G., Kim, S.-J., Rhee, S.-K. (2014). Isotopic signatures of N2O produced by ammonia-oxidizing archaea from soils. *ISME J*., 8: 1115–1125.

Ilodibia, C. V.; Chukwuma, M. U.; Okeke, N. F.; Adimonyemma, R. N.; Igboabuchi, N. A. and Akachukwu, E. E. (2016). Growth and Yield Performance to Plant Density of *Celosia argentea* in Anambra State, Southeastern Nigeria. *International Journal of Plant & Soil Science*, 12(5): 1-5.

Johnson, W. (2007). "A Review of Factors Affecting Plant Growth." Agrikhalsa: What's New.<http://agrikhalsa. tripod.com /plantgrowth.htm>.

Lam, S.S., Ma, N.L., Jusoh, A., Ambak, M.A. (2015). Biological nutrient removal by recirculating aquaponic system: optimization of the dimension ratio between the hydroponic & rearing tank components. *Int. Biodeterior. Biodegrad.*, 102: 107–115.

Lennard, W. And Ward, J. (2019). A comparison of plant growth rates between an NFT hydroponic system and an NFT aquaponic system. *Horticulturae*, 5: 1-16.

Liang, J.-Y., Chien, Y.-H. (2013). Effects of feeding frequency and photoperiod on water quality and crop production in a tilapia–water spinach raft aquaponics system. *Int. Biodeterior. Biodegrad.,* 85: 693–700.

Lucas, E.O. and Lawani, C. (1985). The effect of poultry manure and inorganic fertilizers on the growth of *Corchorus olitorius* in Nigeria. *Afr. J. Agric. Sci*., 12: 141-158.

Lucas, J.S. and Southgate, P.C. (2003). Aquaculture – *Farming aquatic animals and plants*. Oxford: Blackwell Publishing.

Martens-Habbena, W., Berube, P.M., Urakawa, H., de la Torre, J.R., Stahl, D.A. (2009). Ammonia oxidation kinetics determine niche separation of nitrifying Archaea and Bacteria. *Nature*, 461: 976–979.

Nyadanu, D.; Adu Amoah, R.; Kwarteng, A. O.; Akromah, R.; Aboagye, L. M.; Adu-Dapaah, H.; Dansi, A.; Lotsu, F. and Tsama, A. (2016). Domestication of jute mallow (*Corchorus olitorius* L.): ethnobotany, production constraints and phenomics of localcultivars in Ghana. *Genetic Resources and Crop Evolution*, 63(7): 1 -17.

Olaniyan , A.B.; Akintoye, H.A. and Olasanmi, B. (2006). Effect of Different Sources of Nitrogen on Growth and Yield of *Solanum macrocarpon* in Derived Savanna of Nigeria. *Journal of Agronomy*, 5: 182-185.

Panuvatvanich, A., Koottatep, T., Kone, D. (2009). Influence of sand layer depth and percolate impounding regime on nitrogen transformation in vertical-flow constructed wetlands treating faecal sludge. *Water Res*., 43: 2623–2630.

Prein, M. (2002). Integration of aquaculture into crop-animal systems in Asia. *Agricultural Systems:* 71: 127-146.

Rakocy, J. E; Masser, M. P; and Losordo, T. M. (2006). Recirculation aquaculture tank production systems: aquaponics- integrating fish and plant culture. SRAC publication No. 464.

Rakocy J. E; Bailey,D.S; Shultz, R.C; and Danaher, J. J.(2007). Preliminary evaluation of organic waste from two aquaculture systems as a source of inorganic nutrients for hydroponics, ActaHorticult. (ISHS), 742: 201-207.

Rakocy, J., Shultz, R.C., Bailey, D.S., Thoman, E.S. (2003). Aquaponic production of tilapia and basil: comparing a batch and staggered cropping system. South Pacific Soil. Cult. Conf. 648 South Pacific Soil, 63–69.

Read, P., and Fernandes, T. (2003). Management of environmental impacts of marine aquaculture in Europe. Aquaculture, 226: 139–163.

Savidov, N. (2005). Evaluation and Development of Aquaponics Production and Product Market Capabilities in Alberta; Phase 2. Final Report–Project #2004-67905621; Alberta Agriculture, Food and Rural Development: Edmonton, AB, Canada.

Snow, A.M. and Ghaly, A.E. (2008). Use of barley for the purification of Aquaculture wastewater in a hydroponics system. Am. J. Environ. Sci., 4: 89–102.

Stickney, R.R.(1979). *Principles of Warmwater Aquaculture*. A Wiley-Interscience Publication, New York, N.Y. pp 375.

Tilman, D; Cassman, K. G; Matson, P. A; Naylor, R; and Polasky, S. (2002). Agricultural Sustainability and Intensive Production Practices. *Nature* 418: 671-677.

Xia, W., Zhang, C., Zeng, X., Feng, Y., Weng, J., Lin, X., Zhu, J., Xiong, Z., Xu, J., Cai, Z., Jia, Z. (2011). Autotrophic growth of nitrifying community in an agricultural soil. *ISME* J., 5: 1226–1236.

Zhang, L.-M., Hu, H.-W., Shen, J.-P., He, J.-Z. (2012). Ammonia-oxidizing archaea have more important role than ammonia-oxidizing bacteria in ammonia oxidation of strongly acidic soils. *ISME* J., 6: 1032–1045.

Zou, Y., Hu, Z., Zhang, J., Xie, H., Guimbaud, C., Fang, Y. (2016). Effects of pH on nitrogen transformations in media-based aquaponics. *Bioresour. Technol*., 210: 81–87.

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*[1]Owodeinde, F.G, [2]Makinde, S.C.O, [1]Ndimele, P.E., [1]Lawal, O.O., [1]Audu, E.F., [1]Fakoya, K.A., and [1]Raimi, A.B.

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