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Evaluation of a nutrient film aquaponic system for growing of lettuce

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Abstract

Aquaponics as a key factor in the advancement of integrated food production systems and noted potential by simultaneous combination of aquaculture and hydroponics practice. This study evaluate a nutrient film aquaponics system (NFT) for catfish and lettuce. The catfish was raised under different feeding rate treatment: 5% (TRT5%) and 3% (TRT3%). The lettuce was grown with the water from the two treatments and the convectional method (control). The observation were taken in seventh days after transplanting for 4 weeks. The effect of the treatments and water quality on the growth and yield parameters of lettuce were analyzed using analysis of variance and regression analysis at 5% significance level. The result shows that the initial weight of the stocked fish under different treatment tanks had no significant difference ($P<0.05$). In 3-10th weeks, TRT5% is significantly ($P<0.05$) higher than the TRT3%. The TRT5% significantly increased the leaf number and plant height of the lettuce by 27.38% and 28.72% respectively con. The TRT3% significantly increased the leaf number and plant height of the lettuce by 13.10% and 12.34% respectively. The developed mathematical models for number of leaf, plant height, leaf area, weight and productivity had an accuracy of93.2%, 95.6%, 99.7%, 98.28% and 83.32% respectively, Therefore, it should be adopted by small and medium scale aquaponics farmer for significant prediction on lettuce yield as a function of NFT water quality.

Keywords: Aquaponics; Fish feeding rate; Vegetables; Water quality

1. Introduction

Today crop production and fish farming takes up large areas of the planet's surface and negatively affects the ecosystem in a variety of ways, including by causing soil erosion, contaminating the land and groundwater with pesticides, fertilizers, and animal waste, and producing greenhouse gases (Goudie and Heather, 2013). One of the main issues with agricultural production, particularly in the least developed regions with a lack of resources, is the lack of arable land area. Another issue is the degradation of water scarcity. This should prompt us to reconsider how food is produced. Although fish consumption among consumers has been rising, ocean fish catches have been declining. Aquaculture is one of the fastest-growing sectors of modern agriculture, which involves the cultivation of freshwater and marine plants and animals (Rizal et al, 2018). The environmental impact is greatly reduced when fish farming and plant cultivation are combined in closed aquaponic systems. Since aquaponic systems can be practically waste-free, they have little discernible impact on the land.

Aquaponics is the symbiotic fusion of the established fields of hydroponics and aquaculture (FAO, 2014). In an enclosed, recirculating system, fish and plants are combined in aquaponics, a type of sustainable agriculture. Aquaponics is regarded as a type of sustainable agriculture since it effectively utilized both non-renewable and on-farm resources while maintaining the farm's economic viability (Jeffrey and Ricson, 2018). It combines the recirculating aquaculture

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system (RAS), which grows plants without soil in moving water nutrient-rich, with hydroponics. A typical aquaponic system includes a hydroponic unit, a biofilter, a tank for solid waste collection, and sometimes a sump tank. For the health of the fish in RAS, it's critical to maintain adequate water quality by removing dissolved nutrients and solid waste that, in excessive concentrations, could be poisonous to fish. Large-scale fertilizer releases can result in eutrophication, which can disturb the ecology and create changes in the local fauna and algal blooms (Lekang, 2013).

In terms of the environment, aquaponics stops aquaculture wastewater from leaking and contaminating the watershed. A better level of water and production management is also made possible by aquaponics. Because aquaponics doesn't use chemicals for fertilizer, pest management, or weed control, food is safer from possible chemical residues. Aquaponics can increase quality of life in terms of the social sphere since it allows for the cultivation of foods that are suitable for local climates and cultures. Aquaponics can also incorporate livelihood measures to help impoverished and landless households secure food and modest revenues. In order to ensure the empowerment and emancipation of women in underdeveloped nations, domestic food production, access to markets, and skill development are essential tools, and aquaponics can lay the groundwork for equitable and long-term socioeconomic growth. Because protein is sometimes deficient in small-scale farming, fish protein is a helpful addition to the diets of many people. Common aquaponics system include media filled growth beds, bed raft system and nutrient film technique (FAO, 2014).

In the NFT system, water from the fish tank circulates through filters, plant grow beds, and back to the fish tank (Somerville et al, 2014). A mechanical filter in the filter removes the solid waste from the water while a biological filter treats the dissolved trash. The bio filter gives bacteria a place to transform ammonia, which is poisonous to fish, into nitrate, a more readily available fertilizer for plants. The name of this process is nitrification. Nitrate and other nutrients are absorbed by plants as the water flows through plant grow beds, purifying the water before it is returned to the fish tank. The procedure enables symbiotic growth of microorganisms, plants, and fish (Pantanella et al, 2014).

Due to intense cropping, global warming/climate change, and the careless use of pesticides, problems with agricultural land use such as soil depletion, pest infestation, chemical interference, water scarcity, and other environmental factors are becoming increasingly serious. In this way, aquaponics prevents nutrient waste by reusing nutrients and maintains high nutrient concentrations for healthy plant and fish growth. The technology invariably improves the effectiveness of irrigation techniques, along with agriculture and fishery productivity. Systems are divided into categories based on how nutrients are delivered to plants in hydroponic systems, such as floating polystyrene foam sheets (floating rafts), the nutrient film technique (NFT), or media-filled growth beds positioned either horizontally or vertically. Aquaponic technology is regarded as being environmentally benign because it utilizes non-renewable resources very effectively, as seen by almost minimal waste discharge (Rizal et al., 2018; Sommerville et al., 2014). Therefore, this study a nutrient film aquaponics system is adopted for the evaluation of growth and yield of lettuce and catfish in.

2. Material and methods

2.1. Study Location

This study was carried out in Aquaponics structure at Agricultural and Environmental Engineering experimental farm site at Obanla, Federal University of Technology, Akure, Ondo State Nigeria, (7.2995^{0}N, 5.1471^{0}E). As a tropical area, Akure has a population density of 218 people/km^2 with high temperature throughout the year. The average daily temperature is 26 ˚C with a range between 18 ˚C and 35 ^{0}C. Mean annual relative humidity of about 80% and relief is about 396m above sea level (Odubanjo*et al*, 2011). Akure has an average annual rainfall ranged from 1405 mm to 2400mm of which rainy season accounts for 90% and the month of April marks the beginning of rainfall (Akinbile, 2006; Olanrewaju and Ilemobade, 2009, Mohammed et al, 2009; Olagunju and Akinyemi,2015).

2.2. Aquaponics System Design (NFT System)

Two 1 m^3 fish tanks were built and fitted with piping for water recirculation to create an aquaponics system based on the stocking density, or the amount of water or surface area per fish, which adds to environmental conditions that affect fish growth. To increase the amount of dissolved oxygen in the fish tank, a water pump with a capacity of 0.5 horsepower was installed to move water from the fish tanks into the biofilter, which is then dumped into the plant culture, and then back to the fish tanks by gravity through the shower cap. The filter's primary purpose was to remove suspended particulates and prevent bacteria from digesting them when they collected (nitrification). It was created by filling a clear plastic container with carefully arranged maize cubes, covering it with synthetic net to act as a strainer, and then covering it with white pebble stones to act as weight. This prevented the maize cubes from floating and also promoted nitrification in the filter. To protect it from the direct sun's damaging rays, the intended aquaponics system was placed beneath a cover shed with dimensions of 4 m x 6 m x 4 m. Figure 1 show the isometric, orthographic and exploded view of the designed aquaponics system.

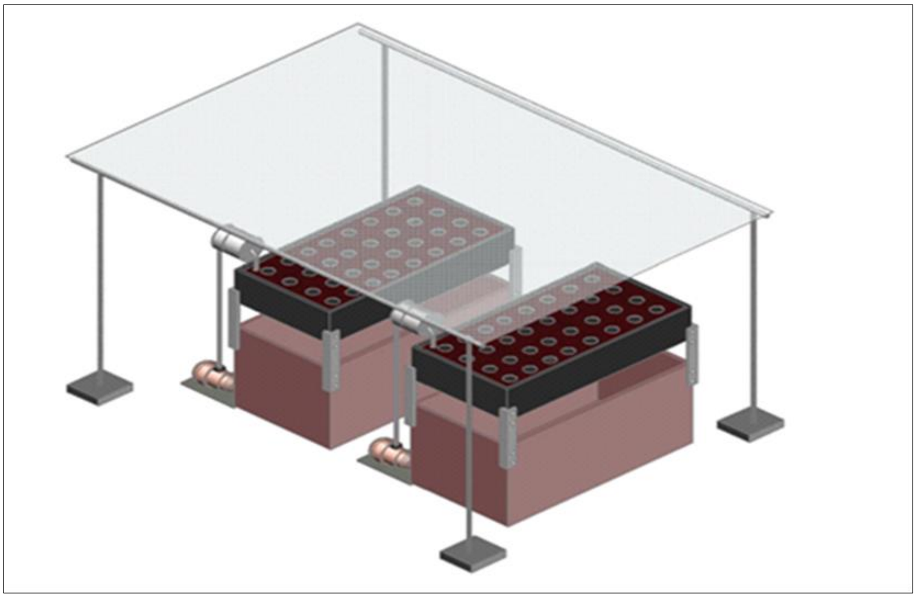

Figure 1 Isometric view of the NFT system

2.3. Materials

Two 1000-liter tanks with the heads cut off, a 0.5 horsepower water pump, lettuce seeds in sachets, single-perforated disposable cups, cotton wool used as a grow bed and nutrient medium for the lettuce plants, seventy pieces of life catfish, floating fish food, an infrared thermometer used to measure the temperature in the aquaponics system, and other materials were used in this study. fish and lettuce are weighed using an electronic balance (HZT-A 30000); lettuce culture tray for growing lettuce traditionally; computerized calliper (Power-fix) for measuring plant dimensions.

2.4. Experimentation

The NFT system comprise of 2 circulatory system of aquatic culture and plant culture for each the treatments. The experimentation process was in multiphase which involves: stocking of fish, fish feeding, lettuce nursing, seedling transplanting and growing in the NFT system.

2.4.1. Stocking of fish

The two fish tanks in the design NFT system were filled with fresh water from the bore hole precisely on the 18th of April 2018 after carrying out the water test to determine the physical, chemical and biological property of the water that befit the fishes. The first and second aquatic tanks was stocked on the 19th of April 2018 at the same time differently with juvenile catfishes *(Clarias gariepinus*) of relatively equal average sizes of ~6 grams, respectively to make comparative study on how the effluent with respect to different feeding rate of 5% and 3% respectively relative to the body weight of total stocked per fish treatment tank. The stocking density for each tank was 35 fishes per 0.6m^3 of water in 0.8m^3 transparenttank. The water temperature on the first day the fishes were stocked was 28 ˚C.

The fishes in the two different aquatic tanks was subjected to two different feeding rate: 5% and 3%. The commercial fish farmers employ the 5% of the average body weight and number stocked as the standard feeding rate for fishes within range of fingerlings and juvenile (FAO, 2014). The 3% was considered as a treatment to reduce the probability of food wastage.However, the feeding rate changes with respect to the average weight of fish as the weighing was carried out once every week for the different treatments. The analytical fish feed constituent as copied from the label attached to the feed nylon package is shown in the Table 1. The feeding frequency of the fishes in each of the treatments were determined based on observation of how responsive the fishes are to picking of feed served within the first 5 minute. The feeding frequency was relative to the feeding rate i.e. the quantity in grams of feed served. Floating feed of 2 mm size was fed to the fishes in the two treatments for the first three week after which feed of 3 mm size was fed to the fishes for the rest of the period.

Table 1 Analytical constituent of the fish feed

Composition	Value
Crude Protein	45%
Crude Fat	12%
NFE	24%
ASH	6%
P – Total	1%
Na – Total	0.2%
Ca – Total	0.8%

2.4.2. Growing of lettuce seed

Lettuce variety called Grace Lake was later purchased from Premier brand seeds and planted on soil bed in the seedling tray and water with borehole water. After 15 days of germination, it was transplanted to the lettuce culture with cotton bed (5cm) in a disposable cup approach. The cup was single perforation underneath with few white pebbles their in (for submersion), the cotton wool is laid on the pebbles as a growing media. Over thirty pieces of these cotton grow bed was arranged on wooden tray of square shape of 0.6m x 0.6m and 0.15m deep in dimension and this was used a the control experiment.

2.5. Measurements

To quantify the performance of the NFT systems, some parameters which include water quality, fish performance, and lettuce performance were taken using data collection interval of 7 days (1week)

2.5.1. Water sampling and data collection

Effluent water samples was collected separately using 0.75 litres transparent bottle each for the two aquaculture treatment tanks respectively once a week for analysis. The quality parameters of water in the system includes the pH level, electrical conductivity (EC), ammonia (NH_4), nitrate (NO_3), nitrite (NO_2) content, dissolved oxygen (DO) and water temperature(T). colorimetric method was used for the measurement of ammonia, nitrate and nitrite.Extech instrument DO700 was used for the measurement of pH, dissolved oxygen (DO) and electrical conductivity using an by inserting the probe into the collected samples, while the temperature was determined directly using infrared thermometer (HCIYET HT – 866).

2.5.2. Fish sampling and data collection

15 catfish were random sampled from each of the two aquaponics tanks. The samples where weight in the group of 3 using an electric balance (HZT – A3000) as shown in Plate 3.3. The average weight per fish in the two treatments were taken for further analysis. This process was repeated and the weightwas recorded once in a week throughout the period for which the transplanted lettuce gets matured.

2.5.3. Plant sampling and data collection

From the lettuce culture, five plant samples were randomly selected from the grown bed of each treatments and the conventionally grown lettuce to determine the number of leaf, plant height, leaf area and weighed once in a week. This weight of the lettuce was done using an electric balance (HZT – A3000) as shown in Plate 3.4 and digital venier caliper for measuring the length and breadth of the lettuce plants. This process was carried out weekly for data collection for four weeks during which the lettuce gets matured.

2.5.4. Determination of leaf area, yield and productivity

The leaf area was measured as the product of the leaf length and breadth as shown in Equation 1. The yield of lettuce plants in each treatment was evaluated based on average weight of the lettuce per plant and the average productivity was measured as the change in the plant weight per day using Equation 2,

$$LA = LL \text{ x LB} \ldots\ldots\ldots\ldots\ldots(1)$$

$$P = \frac{W}{DAT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where;
P is the productivity;
W is average weight of lettuce;
LA is Leaf Area of Lettuce;
LL is the leaf length;
BL is the leaf breadth; G is the growth
DAT isthe number of days after transplanting.

2.6. Experimental Design and Data Analysis

The design involves in three treatments which are control, TRT5% and RT3%. The convectional lettuce that was planted in a box was used as the control experiment. The lettuce plant grown in the NFT system with catfish feeding rate of 5% and 3% were represented by the TRT5% and TRT3% respectively. The estimation of the feeding rate is shown in Equation 3 (Dasuki et al., 2011).

$$FR = (TRT\ (\%) \times W \times n\ /\ 1000) \ldots\ldots\ldots\ldots (3)$$

Where;
TRT is the desired percentage feeding rate in the treatment,
W is the average weekly body weight of fish (g)
n is the number of stock.

After transplanting, the fish and lettuce performance was measured in seven days interval for a month (i.e DAT7, DAT14, DAT21 and DAT28). Data obtained were subjected to statistical analysis such as Analysis of Variance (ANOVA) and Turkey Honestly significant difference (HSD) were use to determine the level significance and compare the means of parameters measured under different treatments (TRT5%, TRT3% and convectional)and time at 95% confidence level. Also,type III sum of square analysis wasused to determine quantify the effect of aquaculture water qualities on the growth and yield of the lettuce at 5% probability level. Multivariate linear regression analysis was use to establish the mathematical model for the prediction of the growth and yield parameter of the lettuce as function of the water quality.

3. Results and discussion

3.1. Temperature and Relative Humidity

Figure 2a & b shows the environmental temperature and relative humidity under different planting conditions for the lettuce (TRT5%, TRT3% and control). The temperature ranged from 24.4 to 27.4 °C, 24.2 to 26.9 °C and 24.7 to 27.9 °C for region under TRT5%, TRT3% and control respectively. The relative humidity recorded under the TRT5%, TRT3% and control were in the range of 73.79 to 80.01%, 74.93 to 79.17% and 72.5 to 77.05%, respectively. The TRT3% had the lowest mean temperature (25.48 ± 0.8 °C), followed by TRT5% (25.68 ± 0.88 °C) and control experiment had the highest temperature (26.19 ± 0.99 oC). The relative humidity under the control experiment was 74.18 ± 1.05% and it increase to 76.34 ± 1.52% under TRT5%. The Highest relative humidity (77.2 ± 1.14%) was recorded in the TRT3%. Although, the temperature (24.2 - 27.9 °C) and relative humidity (72.5 - 80.01%) under different treatments falls in a close range. The slight variation in the temperature and the relative values might be due to the correspondence of the location of the NFT system and its proximity to the ray of sun light. However, the mean comparison using turkey test shows a nonsignificant difference ($P<0.05$) in the temperature and relative humidity of the planting region under different treatments.

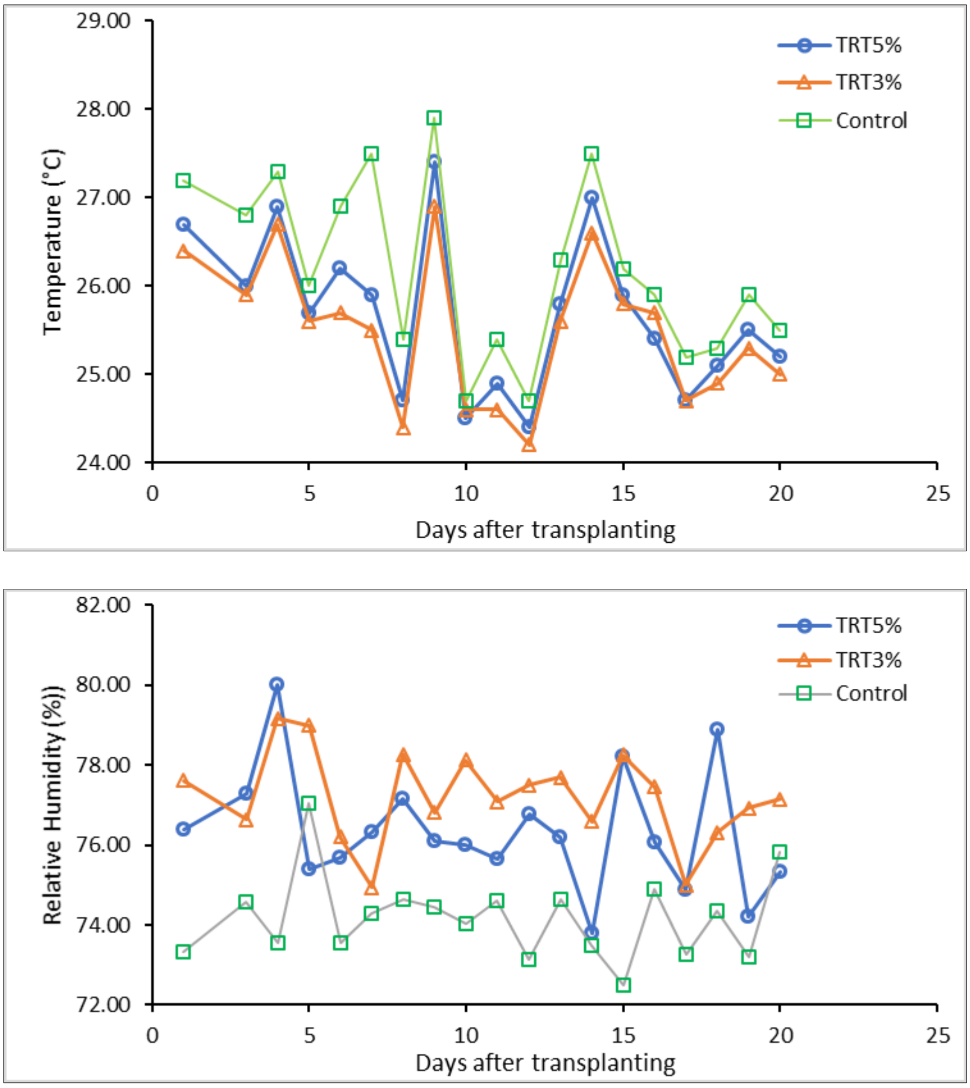

Figure 2a & b Temperature and relative humidity of study location

3.2. Water Samples Parameter

Table 1 show the quality of water in the growing media using nutrient film technique (NFT). The water quality parameter includes nitrogen-based compounds (ammonia, nitrite and nitrate) dissolve oxygen, electrical conductivity, temperature and pH of the system.

3.2.1. Nitrate (NO3), Nitrite (NO2), Ammonia (NH3) in NFT system

From Table 2, the level of nitrite in the fresh water in the NFT system before stocking was at 0.9 Mg/L for both treatments. The value increased continuously until it attains the highest level of 436.54 ± 17.46 Mg/L and 289.19 ± 11.61 Mg/L under TRT5% and TRT3% respectively. Also, the level of ammonia in the NFT system increase from initial value of 0.96 Mg/L increased to 197.69 ± 7.94 Mg/L and 105.41 ± 3.71 Mg/L under TRT5% and TRT3% respectively. Similarly, The level of nitrate in the NFT water increased from initial value of 3.5 ± 0.14Mg/L to 868.74 ± 43.44 Mg/L and 596.44 ± 23.86 Mg/L under TRT5% and TRT3% respectively. The comparison test shows both treatment and time are significant ($P<0.05$) factors that determines the compounds in the NFT water. The increase in the nitrogen-base compounds in the NFT system is due to the gradual build up of ammonia due to the microbiological activity on the left over of fishes feed and their faeces that were later converted to nitrate and nitrite via bacterial nitrification. At the point to observation continuous introduction of clean water and dislodging the NFT system reduce the negative consequence of the compound on the growth of fishes and the lettuce (Rakocy et al., 2006).

Table 2 Effect of treatment and time on the water quality of the Nutrient film technique

Treatments	Time	DO (mg/L)	EC (μs/cm)	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	pH	T (°C)
TRT5%	Initial	5.23 ± 0.05d	3 ± 0.11f	0.96 ± 0.04e	0.9 ± 0.04e	3.5 ± 0.14d	6.17 ± 0.22b	25.8 ± 1.29a
	DAT7	4.99 ± 0.05e	741.68 ± 33.33a	197.69 ± 7.94a	412.67 ± 12.38a	868.74 ± 43.44a	7.7 ± 0.35a	27 ± 1.08a
	DAT14	7.32 ± 0.08b	436.54 ± 17.46c	74.35 ± 3.72c	86.64 ± 3.03c	110.11 ± 4.95c	6.7 ± 0.27b	25.99 ± 0.91a
	DAT21	7.57 ± 0.09a	308.28 ± 12.38e	65.17 ± 1.96c	82.62 ± 2.89c	94.09 ± 4.23c	6.48 ± 0.23b	25.15 ± 0.92a
TRT3%	Initial	5.21 ± 0.05d	3.01 ± 0.09f	0.96 ± 0.03e	0.9 ± 0.04e	3.5 ± 0.14d	6.23 ± 0.25b	25.5 ± 1.13a
	DAT7	4.56 ± 0.03f	546.12 ± 16.38b	105.41 ± 3.71b	289.19 ± 11.61b	596.44 ± 23.86b	7.55 ± 0.23a	26.74 ± 1.28a
	DAT14	4.1 ± 0.04de	346.99 ± 13.93de	66.82 ± 2.67c	39.6 ± 1.78d	73.85 ± 3.32c	6.61 ± 0.27b	25.84 ± 0.83a
	DAT21	4.64 ± 0.07c	356.18 ± 10.69d	53.11 ± 2.4d	41.12 ± 1.23d	65.54 ± 1.97c	6.51 ± 0.2b	25.34 ± 0.81a
TRT		***	***	***	***	***	NS	NS
Time		**	NS	*	*	NS	*	NS
TRT*Time		***	***	***	***	***	**	NS

3.2.2. DO, EC,, temperature, pH level of the NFT system

Prior the experiment, the dissolve oxygen (DO) and electrical conductivity (EC) of the NFT water were still within the permissible limit for effective growing of the catfish and lettuce in both treatments. The initial dissolve oxygen (DO) and electrical conductivity (EC) were 5.23 ± 0.05 Mg/L and 3.01 µs/cm respectively under TRT5% and the initial values were 5.21 ± 0.05 Mg/L and 3.01 ± 0.09 µs/cm under TRT3%. During the experiment, the electrical conductivity of the system increased to 308.28 ± 12.38 µs/cm to 741.68 ± 33.33 µs/cm; and 346.99 ± 13.93 µs/cm to 546.12 ± 16.38 µs/cm under TRT5% and TRT3% respectively. This EC level is above the allowable limit of 5 s/cm, which negatively affects the rate of nutrient absorption by the lettuce and fish and may result in growth retardation. That is the resultant impact. Rakocy et al. (2006) added that the acceptable limit of dissolve oxygen is 5, though. The DO in the NFT system is within the range that permits the fish and lettuce to develop properly. As a result, the DO (moderate amount) boosted lettuce growth and fish activity by strengthening lettuce roots' ability to absorb water and increasing lettuce leaves' growth (Rackocy et al., 2006)

From Table 3, the initial temperature, and pH level of water in the NFT system were 25.8 ± 1.29 ^{o}C and 6.17 ± 0.22 respectively under TRT5% and the initial values were 25.5 ± 1.13 ^{o}C and 6.23 ± 0.25 respectively under TRT3%. The maximum pH was after 4 weeks for both treatments. This confirmed the strong relationship between pH and total nitrogen in the system. The pH is an appropriate meter for the solubility, toxicity of chemicals and heavy metals in water. However, NFT system should maintain a pH around 7 for nitrification efficiency with nutrient solubility (FAO, 2004) and the pH values falls within the permissible range in both treatments.

3.3. Physiochemical Properties of Soil in Conventional Lettuce Culture

The descriptive statistics of the soil properties for the control experiment is shown in Table 3. The result reveals that the soil textural class is sandy loam, this infer that the soil is good for the lettuce plant with the ability to moderately retain moisture. soil nutrients such as total carbon (TC), calcium (Ca), magnesium (Mg), cupper (Cu), iron (Fe), sodium (Na) are all at high level. The level of total nitrogen (TN), zinc (Zn), potassium (K), and manganese (Mn) in the soil is relatively low. The ideal pH range for the majority of aquatic species and crops is between 6.5 to 9.0, according to Timmons and Ebeling (2013). The cation exchange capacity (CEC), a measure of the soil's textural class, is moderate and favourable for lettuce plants. Due to the excessively saline soil, when electrical conductivity (EC) levels are high, lettuce development is negatively impacted. This study's pH is within the acceptable range (6–9.0), indicating that soluble nutrients beneficial to lettuce growth are available.

Table 3 Properties of soil for conventional growing of lettuce

Properties	**Max**	**min**	**Mean ± SD**	**CV(%)**
Sand (%)	67.22	63.94	65.55 ± 1.64	2.50
Clay (%)	17.65	15.97	16.81 ± 0.84	5.00
Silt (%)	18.41	16.82	17.64 ± 0.8	4.54
T.C (%)	1.73	1.61	1.67 ± 0.06	3.59
T.N (%)	0.16	0.14	0.15 ± 0.01	6.67
pH (H2O)	6.49	5.87	6.18 ± 0.31	5.02
Ca (cmo/kg)	4.06	3.75	3.9 ± 0.16	4.10
Mg (cmo/kg)	3.11	2.84	2.98 ± 0.13	4.36
K (cmo/kg)	0.55	0.50	0.53 ± 0.02	3.77
Na (cmo/kg)	0.22	0.20	0.21 ± 0.01	4.76
CEC (cmo/kg)	8.01	7.39	7.7 ± 0.31	4.03
EC (mS/M)	77.91	71.23	74.45 ± 3.35	4.50
H+	0.11	0.10	0.1 ± 0.004	4.00
Mn (ppm)	81.34	75.02	78.44 ± 3.19	4.07
Cu (ppm)	1.52	1.44	1.48 ± 0.04	2.70
Fe (ppm)	173.04	161.28	167.44 ± 5.9	3.52
Zn (ppm)	1.62	1.48	1.55 ± 0.07	4.52

3.4. Growth Rate of Catfish

The progression growth of the catfish under two treatments (TRT5% and TRT3%) in 10 weeks is depicted in Figure 3. as expected, the weight of the catfish increases continuously with time under both treatments. Initially, the weight of the stocked fish under different treatment tanks had not significant difference ($P<0.05$). In the later, the figure shows that the average weight of the catfish under TRT5% is significantly higher than the TRT3%. This could be attributed to quantity of feed given to the catfish, since the percentage difference in the feeding rate treatment is proportional to the growth of the catfish. According to the fitted exponential growth curve, the fish under TRT3% had a growth constant of 0.21. The constant increase by 19.23% and this shows that the treatments of ratio (TRT3% : TRT5%) is proportional to the ratio of the growth constant(5 : 6). The fitted exponential curve can predict the growth of the fish with an accuracy of 98.82% and 94.725% under the treatment of TRT3% and TRT5% respectively.

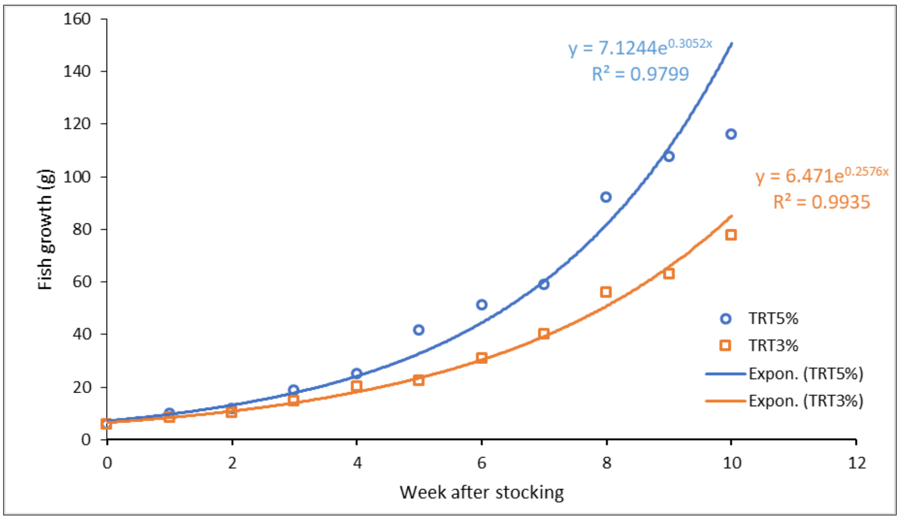

Figure 3 Effect of the different feed treatment (TRT5% and TRT3%) on the growth of fish in an aquaponics system

3.5. Lettuce Growth

The growth of the lettuce was discussed based on the number of leaf (NL), plant height (PH), and leaf area (LA) as shown in Figure 4 The rate of increments in the plant growth was significantly ($P<0.05$) depend on the time. The growth of the lettuce increased continuously with the time (DAT7 – DAT28). 7 days after transplanting, the NL, PH and LA of the lettuce were 5.33 ± 1.75, 5.19 ± 1.66 cm, 151.65 ± 48.29 mm^2 respectively. The NL, PH and LA significantly ($P<0.05$) increased to 31.78 ± 10.59, 17.81 ± 5.96 cm, 873.58 ± 279.16 mm^2 respectively at 28 days after transplanting. The results are consistent with those obtained by Hassan et al. (2017), Islam (2012), Boroujerdnia and Ansari (2007), and Mahmoudi (2005) for the growth of lettuce under various treatments (16.94 - 35.01 cm and 11.54 - 31.77 for plant height and number of leaves, respectively). The result of the analysis of variance and mean comparison (Tukey's honestly significant difference) shows that the treatments (Control, TRT5% and TRT3%) has a significant effect on the plant growth. The lowest value of NL, PH, and LA were 28.0 ± 1.0, 15.67 ± 0.55 cm and 845.74 ± 29.8 mm^2 respectively was recorded under the control experiments.

The TRT5% significantly increased the NL and PH of the lettuce by 27.38% and 28.72% respectively. The TRT3% significantly increased the NL and PH of the lettuce by 13.10% and 12.34% respectively. However, the LA of the lettuce significantly increased by 8.82% under the treatment of TRT5%. Meanwhile the LA of the lettuce under TRT3% has no significant difference ($P<0.05$) from the control experiment. The weight of leafy vegetables can be used to estimate the eventual yield because the importance of vegetative growth is simply to generate a large enough photosynthesis to achieve maximum yields. However, the total number of leaves might also relate to a vegetable's yield value (Sadik et al., 2011; Gil et al., 2012; Palil et al., 2018).

The effect of the water quality on the growth of the lettuce was analyzed using type III sum of the square analysis and the regression. The ANOVA result in Table 4 shows that the pH and T of the nutrient film system has no significant effect on the growth parameters of the lettuce. In all the measured water quality parameter. The variation in the number of leaves significantly ($P<0.05$) depends on the dissolve oxygen and the nitrogen-based compounds (Ammonia, Nitrite and Nitrite). According to the FAO report from 2004 and Mariana et al. (2017), nitrogen-based compounds such urea, ammonium, nitrite, and nitrate are important components that support the growth of plant tissue as long as the concentration is moderately available in the planting medium.

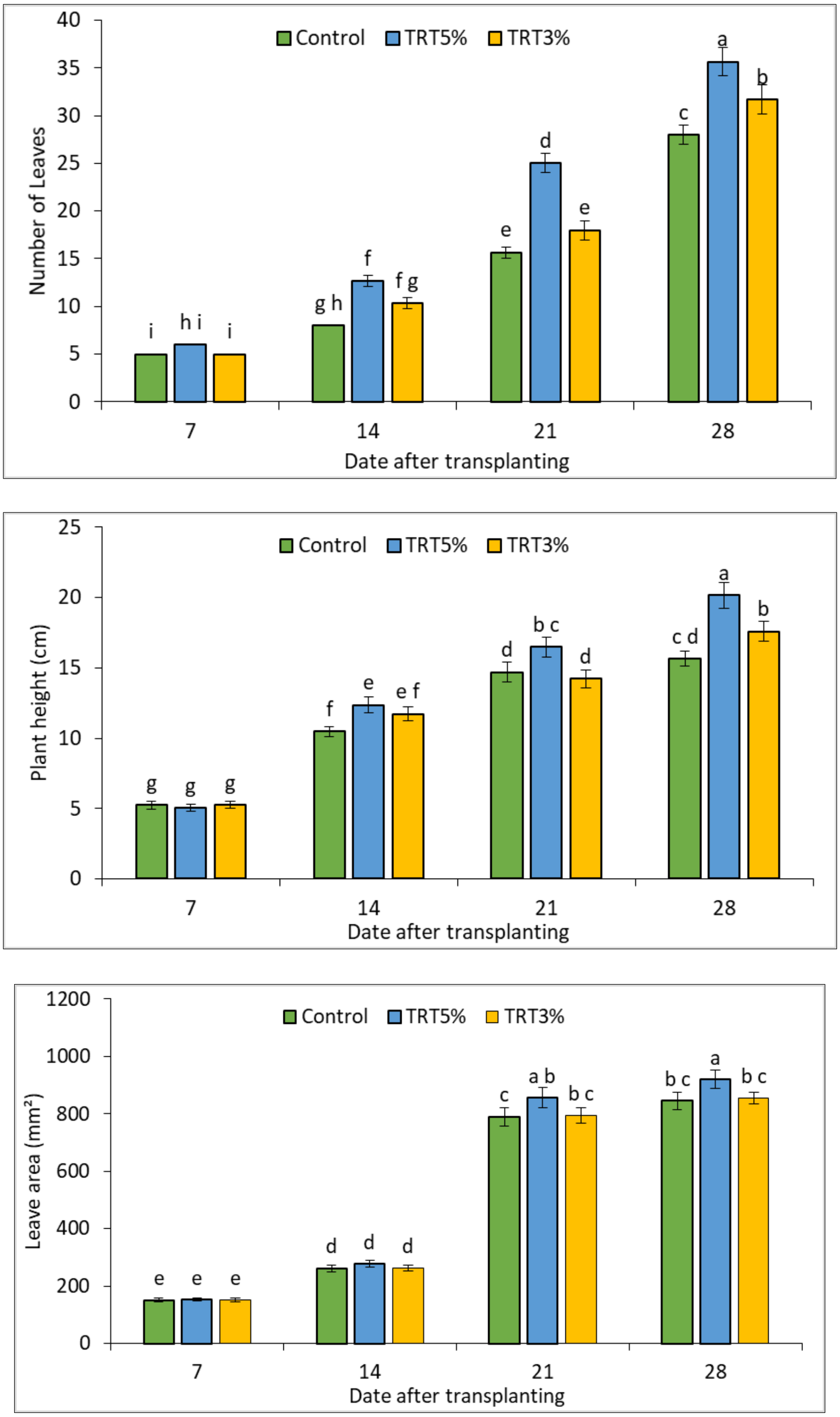

Figure 4a Lettuce growth based on the number of leaf (NL), b) plant height (PH), and c) leaf area (LA)

Table 4 The effect of water quality on the growth performance of lettuce

Growth parameter	Source	DF	Sum of squares	Mean squares	F	Pr> F	Sig.
Number of leaf	Model	7	1534.85	219.26	34.12	0.0000	***
	DO	1	366.38	366.38	57.01	0.0000	***
	EC	1	22.73	22.73	3.54	0.0894	NS
	NH_3	1	38.20	38.20	5.94	0.0350	*
	NO_2	1	155.06	155.06	24.13	0.0006	***
	NO_3	1	161.51	161.51	25.13	0.0005	***
	pH	1	2.52	2.52	0.39	0.5454	NS
	T	1	0.94	0.94	0.15	0.7095	NS
	Error	10	64.27	6.43			
	Corrected Total	17	1599.11				
Height	Model	7	159.89	22.84	57.53	0.0000	***
	DO	1	30.61	30.61	77.11	0.0000	***
	EC	1	6.50	6.50	16.36	0.0023	**
	NH_3	1	0.83	0.83	2.10	0.1781	NS
	NO_2	1	9.34	9.34	23.52	0.0007	***
	NO_3	1	9.54	9.54	24.04	0.0006	***
	pH	1	0.01	0.01	0.03	0.8713	NS
	T	1	0.06	0.06	0.15	0.7087	NS
	Error	10	3.97	0.40			
	Corrected Total	17	163.86				
Leaf area	Model	7	1402601.80	200371.69	936.87	0.0000	***
	DO	1	26125.66	26125.66	122.15	0.0000	***
	EC	1	2113.00	2113.00	9.88	0.0105	*
	NH_3	1	5979.92	5979.92	27.96	0.0004	***
	NO_2	1	8560.08	8560.08	40.02	0.0001	***
	NO_3	1	2142.14	2142.14	10.02	0.0101	*
	pH	1	19.43	19.43	0.09	0.7693	NS
	T	1	119.33	119.33	0.56	0.4723	NS
	Error	10	2138.73	213.87			
	Corrected Total	17	1404740.54				

*** = P<0.001; **= P<0.01; *= P<0.05; NS = Not significant

The regression model of the number of leaf as a function DO, NH_3, NO_2 and NO_3 is shown in equation 4 with an accuracy of 93.2%. The model shows that a unit increase in the DO and NO_3 of the water increased the number of leaves by 145.87 and 1.91, respectively. Whereas the increase in the NH_3 and decreased the number of leaves by 0.46 and 3.86, respectively.

$$NL = 8.07 + 22.77DO - 0.21NH_3 - 0.57NO_2 + 0.3NO_3 \text{..........................} 4$$

Where;
NL is the number of leaf,
DO is the dissolve oxygen,
NH_3 is the ammonia,
NO_2 is the nitrite content
NO_3 is the nitrate content.

The dissolve oxygen, electrical conductivity, nitrite, and nitrate are the water quality parameters that has a significant ($P<0.05$) effect on the height of the lettuce. Equation 5 depict the developed relationship between the height of the lettuce, DO, EC, NO_2 and NO_3 with an accuracy of 95.6%. The model shows that a unit increase in the DO and NO_3 of the NFT water increased the plant height by 5.57 cm and 0.06 cm, respectively. A unit increase in the EC and NO_2 decreased the plant height by 0.02 cm and 0.11 cm, respectively.

$$PH = 15.68 + 5.67DO - 0.02EC - 0.11NO_2 + 0.06NO_3 \ldots\ldots\ldots\ldots 5$$

Where;
PH is the plant height,
DO is the dissolve oxygen,
EC is the electrical conductivity,
NO_2 is the nitrite content
NO_3 is the nitrate content.

The leaf surface area the lettuce significantly ($P<0.05$) depends on the dissolve oxygen, electrical conductivity, and nitrogen-based compounds (Ammonia, Nitrite and Nitrite). The empirical model for predicting the leaf area as a function of DO, EC, NH_3, NO_2, and NO_3 is shown in Equation 6 with an accuracy of 99.7%. The model shows that a unit increase in the DO, NH_3 and NO_3 of the NFT water increased the leaf are by 199.95 mm^2, 1.93 mm^2, and 1.36 mm^2 respectively. The increase in the EC and NO_2 decreased the leaf area by 0.46 and 3.86 respectively.

$$LA = 599.22 + 199.95DO - 0.21EC + 1.93NH_3 - 4.68NO_2 + 1.36NO_3 \ldots\ldots\ldots 6$$

Where;
LA is the leaf area,
DO is the dissolve oxygen,
EC is the electrical conductivity,
NH_3 is the ammonia,
NO_2 is the nitrite content
NO_3 is the nitrate content.

3.6. Yield of Lettuce

The yield of the lettuce was discussed based on weight and the productivity as shown in Figures 5. The weight and productivity of the lettuce increased continuously with the observation period (DAT7 – DAT28). The weight and productivity of the lettuce were about 82.89 ± 1.54 $gplant^{-1}$ and 3.27 ± 0.22 $gplant^{-1}day^{-1}$ respectively at 7 days after transplanting. The weight and productivity of lettuce significantly ($P<0.05$) increased to 344.44 ± 24.92 $gplant^{-1}$ and 10.16 ± 0.89 $gplant^{-1}day^{-1}$ respectively after 28 days of transplanting. The ANOVA result and mean comparison test (Tukey's honestly significant difference) shows that the treatments (Control, TRT5% and TRT3%) has a significant effect on the weight and productivity of the lettuce. At the end of the experiment, the lowest weight (327.33 ± 18.58 g/plant) and productivity (9.55 ± 0.66$gplant^{-1}day^{-1}$) of lettuce was recorded under the control experiments. The TRT5% significantly ($P<0.05$) increased the weight of the lettuce by 13.85%. the TRT3% increased the weight of the lettuce by 1.83%. Statistically, the difference in the weight of lettuce under TRT3% and control experiment is not significant at $P <0.05$. The productivity of the lettuce significantly increased by 16.96% and 2.24 % under the treatment of TRT5% and TRT3% respectively. Statistically, the difference in the productivity of lettuce under TRT5%, TRT3% and control experiment are not significant ($P <0.05$). Similar to this, Maboko and Du-Plooy (2008) observed that a soilless approach increased lettuce yield and quality. In a paper that is comparable to this one, Niederwieser (2001), Andriolo et al. (2006), and Maboko and Du-Plooy (2009) describe plant spacing as another element that affects lettuce production in a soilless culture technique as opposed to convectional planting

The effect of the water quality on the yield of the lettuce was analyzed using type III sum of the square analysis and the regression. Also, Table 5 shows that the pH, and T of the nutrient film system has no significant effect on the yield of the lettuce. the variation in the lettuce weight significantly ($P<0.05$) depends on the dissolve oxygen, electrical conductivity and two nitrogen-based compounds (nitrate and nitrite).

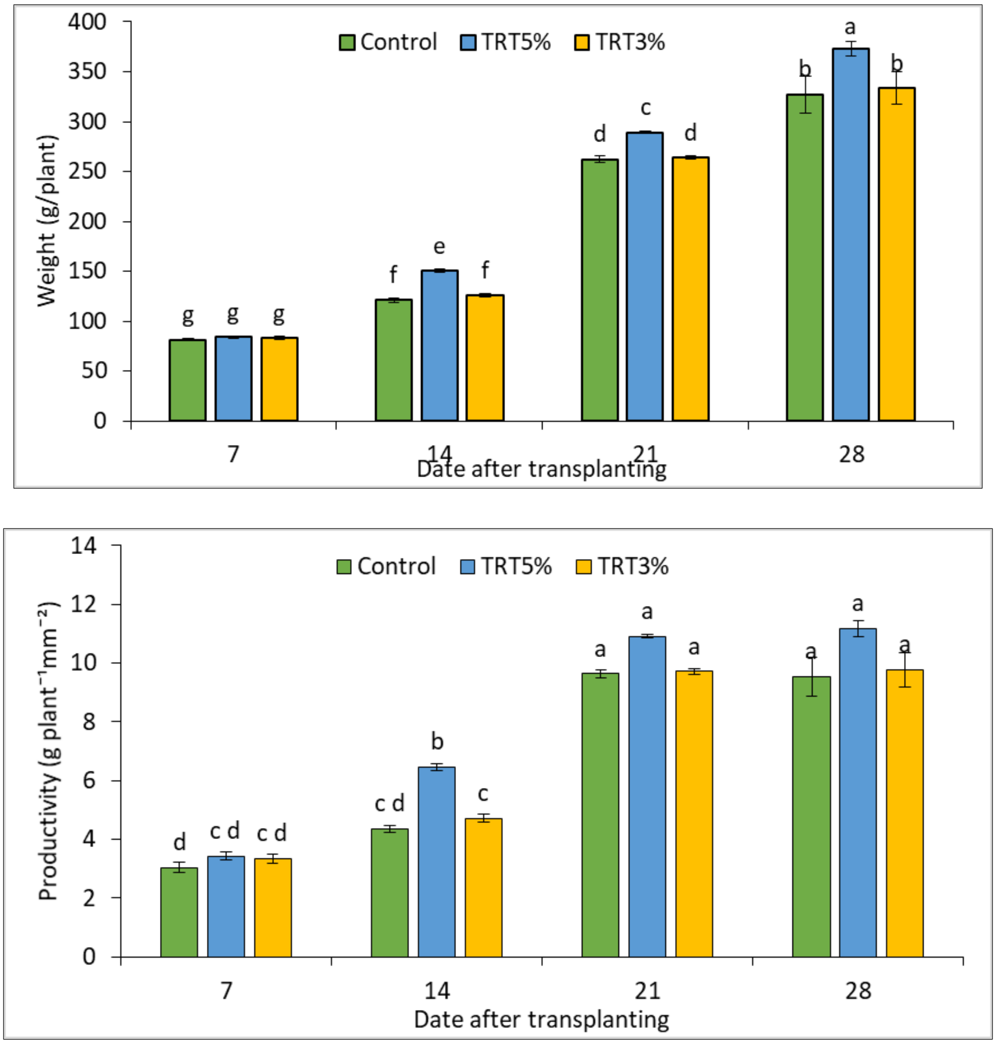

Figure 5 Lettuce yield under different treatment in the NFT system

The regression model of the lettuce weight as a function DO, EC, NO_2 and NO_3 is shown in Equation 7 the DO and NO_3 of the water increased the lettuce weight by 145.87 gplant^{-1} and 1.91 gplant^{-1} respectively. Whereas the increase in the and NO_2 decreased the lettuce weight by 0.46 gplant^{-1} and 3.86 gplant^{-1} respectively.

$$W = 280.4 + 145.87DO - 0.46EC - 3.86NO_2 + 1.91NO_3 \ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where;
W is the weight of lettuce,
DO is the dissolve oxygen,
NO_2 is the nitrite content
NO_3 is the nitrate content.

For the lettuce productivity, the model developed as a function DO, EC, NO_2 and NO_3 is shown in Equation 8 with 0.8332 coefficient of determination. The model shows that a unit increase in the DO of the NFT water increased the lettuce weight by 2.4 gplant^{-1} day^{-1} and a unit the increase in the NH_3 decreased the lettuce productivity by 0.01 gplant^{-1} day $^{-1}$. This demonstrates that the ammonia content of the NFT water is excessive, which reduces the lettuce crop output (FAO, 2004). According to Morgan (2005), urea-treated soils and plants in our treatment resulted in heavier cobs of corn and higher kernel weights in the soil. A plant treated with ammonia produced more ears than a plant grown in untreated soil. By treating the plant with urea and ammonia, Akpan-Idiok et al. (2012) also increase the production of the okra plant.

$$P = 6.47 + 2.4DO - 0.01NH_3 \ldots\ldots\ldots\ldots 8$$

Where;
P is the plant productivity,
DO is the dissolve oxygen,
NH_3 is the ammonia

Table 5 Effect of NFT water quality on the lettuce yield

Yield parameter	**Source**	**DF**	**Sum of squares**	**Mean squares**	**F**	**Pr> F**	**Sig.**
Weight	Model	7	145387.66	20769.67	117.26	0.0000	***
	DO	1	14618.78	14618.78	82.53	0.0000	***
	EC	1	2689.17	2689.17	15.18	0.0030	**
	NH_3	1	118.21	118.21	0.67	0.4330	NS
	NO_2	1	6637.19	6637.19	37.47	0.0001	***
	NO_3	1	6193.16	6193.16	34.96	0.0001	***
	pH	1	463.58	463.58	2.62	0.1368	NS
	T	1	225.06	225.06	1.27	0.2860	NS
	Error	10	1771.29	177.13			
	Corrected Total	17	147158.94				
Productivity	Model	7	102.36	14.62	199.93	0.0000	***
	DO (mg/L)	1	1.39	1.39	19.07	0.0014	**
	EC (µs/cm)	1	0.04	0.04	0.54	0.4807	NS
	NH_3 (mg/L)	1	2.08	2.08	28.50	0.0003	***
	NO_2 (mg/L)	1	0.05	0.05	0.71	0.4190	NS
	NO_3 (mg/L)	1	0.02	0.02	0.26	0.6203	NS
	pH	1	0.14	0.14	1.88	0.2008	NS
	T (°C)	1	0.13	0.13	1.71	0.2198	NS
	Error	10	0.73	0.07			
	Corrected Total	17	103.09				

*** = $P<0.001$; **= $P<0.01$; *= $P<0.05$; NS = Not significant

4. Conclusion

The following conclusion were made based on the performance of the catfish and lettuce in the NFT system.

- The weight of the stocked fish under different treatment tanks had not significant difference ($P<0.05$). In the later, the average weight of the fish under TRT5% is significantly ($P<0.05$) higher than the TRT3%.
- The TRT5% significantly increased the NL and PH of the lettuce by 27.38% and 28.72% respectively. The TRT3% significantly increased the NL and PH of the lettuce by 13.10% and 12.34% respectively.
- The LA of the lettuce significantly increased by 8.82% under the treatment of TRT5%. Meanwhile the LA of the lettuce under TRT3% has no significant difference ($P<0.05$) from the convectional mode of planting

- The growth and yield of the lettuce plant significantly (P<0.05) depends on the dissolve oxygen and the nitrogen-based compounds (Ammonia, Nitrite and Nitrite).
- The developed mathematical models significantly predict of the development of number of leaf, plant height, leaf area, weight and productivity of the lettuce plant as a function of water quality with an accuracy of 93.2%, 95.6%, 99.7%, 98.28% and 83.32% respectively.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest regarding the publication of this paper.

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