Original Research Article

Growth and yield performance of *Lactuca sativa* L. grown in hydroponics using fish effluents and inorganic fertilizer

ABSTRACT

Aquaponics is an emerging sustainable food production technique where waste from fish culture is used as a source of nutrients for crops grown in hydroponics system. The present study was conducted at the Agriculture Research and Development Center, Sita Eliya, Nuwara Eliya, Sri Lanka during November 2015 to January 2016, to compare the yield of lettuce (*Lactuca sativa* L.) grown in hydroponics using fish effluents and inorganic fertilizer. The experiment was laid in a Completely Randomized Design with 5 treatments and 4 replicates. The different nutrient solutions used as the treatments of this experiment were water (T1), Albert's solution (T2), Catla waste water (T3), Common Carp waste water (T4) and Tilapia waste water (T5). Each nutrient solution was tested for its nutrient composition, temperature, pH and electrical conductivity throughout the experimental period. The plant growth and yield parameters measured were plant height (cm), number of leaves, canopy diameter (cm), root length (cm), fresh weight of plant, leaves and roots (g), dry weight of leaves and roots (g) and, yield (ton/ha). The fish related parameters measured were body weight (g), initial and final stocking density (g/m3) and the mortality percentage. The results showed that T2 stood out ($p<0.05$) with the highest plant height (12.27cm), canopy diameter (14.80cm), number of leaves (12) and root length (15.04cm), exhibiting a vigorous growth compared to the other treatments. A remarkable yield and shoot and root weight (fresh and dry) were also shown by T2 over the other treatments. Fish waste water in T3, T4 and T5 did not fulfill the nutrient requirement of lettuce due to the limited nutrients; nitrogen, phosphorus and potassium) produced by fingerlings. Therefore, these fish waste solutions need to be improved by increasing the feed quality and selecting fish within a suitable age range in order to obtain a yield comparable to T2, which is the commercially available Albert's solution.

Keywords: albert's solution, aquaponics, fish waste water, lettuce

1 INTRODUCTION

Hydroponics is a term derived from the Greek words; hydro' which means water and, 'ponos' which means labour. It is a technique of growing plants in soil-less condition with their roots immersed in nutrient solution (Beibel, 1960) or in an inert medium, such as perlite, gravel, or mineral wool. Hydroponics can be done in several ways and the deep flow system is one out of them, where water is pumped up from a reservoir tank and across plant roots (Vega et al. 2023). The fertilizer solution is kept deep enough to cover the roots, and typically continuous circulation is used to provide an adequate supply of oxygen in the root zone.

Aquaponics is an emerging sustainable food production technology that combines hydroponics and aquaculture to grow crops and fish without the need for soil (Shafahi& Woolston, 2014). In the face of drought, declining soil fertility, and climate change, aquaponics is revolutionising agriculture and is predicted to increase food security in developing countries (Obirikorang et al., 2021). In addition, fish waste that is high in ammonia is incorporated into the plant bed of an aquaponic system, where it acts as a bio-filter and absorbs nitrate, creating a low-cost symbiotic interaction between the fish and the plant (Shafahi& Woolston, 2014). The primary problems with these two systems, which are the need for nutrient-rich water to serve as a fertilizer with all of the nutrients and minerals required for plants grown hydroponically and the need for sustainable methods of filtering or discarding nutrient-rich fish waste in aquaculture, are resolved by aquaponics. (Nelson, 2008). The nutrients, largely in the form of ammonia are converted by denitrifying bacteria in the hydroponic grow bed into forms readily up taken by plants for energy and growth. The cycle of nutrient flow is continuous and is restarted by adding fresh new water to the fish enclosure, where it becomes one of the distinct benefits of an aquaponic system over conventional irrigation systems due to its ability to conserve water more efficiently (Shafahi& Woolston, 2014). In brief, aquaponics is an advanced agriculture-aquaculture approach (Obirikorang et al., 2021) where the waste of one biological system becomes nutrients for another biological system (Diver, 2006).

A wide variety of fish species can be grown at high density in tanks in recirculated aquaculture or aquaponic systems. However, the suitability of a certain fish species for aquaponics production will be decided by the system design and the specifics of the local market where they will be produced (Pinho et al., 2021). By far, lettuce (Lactuca sativa) is one of the most popular vegetables to grow in aquaponic systems. It is a hardy plant that has a fast growth rate (Resh, 2001) and allows for a quick realized profit and turnover of nutrients in the system (Rakocy et al. 2006). Therefore, the present study was conducted to compare the yield of lettuce grown in hydroponics using fish effluents (Catla, Common Carp and Tilapia) and inorganic fertilizer (Albert's solution).

2 MATERIALS AND METHODS

2.1 Experimental Site

The study was conducted in a poly-tunnel at the Agriculture Research and Development Center, SitaEliya, NuwaraEliya, Sri Lankaduring November 2015 to January 2016. During the experimental period, the mean daily temperature was 14.8^0C - 19.5^0C, average rainfall was 24.5 mm - 100.6 mm and average relative humidity was 93% - 96%.

2.2 Treatments and Experimental Design

The experiment was laid out in a Completely Randomized Design with five treatments (Table 1) and four replicates.

Table 1: Treatment details of the experiment

Treatment Code	Description
T1	Water
T2	Albert's solution
T3	Waste water from Catla fish tank
T4	Waste water from Common Carp fish tank
T5	Waste water from Tilapia fish tank

2.3 The Aquaponic System

Five similar sized tanks (1.21m × 3.04m × 0.91m) were used to rear the fish (Catla, Common Carp and Tilapia) separately.Poly Vinyl Chloride (PVC) pipes of 0.1m diameter were used for the Deep Flow Hydroponic System. The fish tanks and hydroponic units were connected using 0.01m inch PVC pipes. Aquarium motors were used to circulate the nutrients.

2.4 Crop Establishment

Lettuce (*Lactuca sativa* L.) seeds of the variety 'Rapido' were planted in net pots (0.05m in diameter) filled with sterilized coir dust and kept in a protected house. Two weeks later, pots containing healthy and vigorous seedlings were selected from the nursery and used for the experiment.

2.5 Nutrient Circulating System

Seedlings selected from the nursery were placed in the hydroponic system and the 5 different nutrient solutions (treatments) were circulated throughout the dayseparately in them. There were 12 plants in each circulating system. Nutrients were supplied to the seedlings using commercially available Albert's solution (T2), and waste water from fish tanks (T3, T4, T5).

2.6 Albert's Solution

2g of Albert's fertilizer was added to 1l of water to prepare the nutrient solution for T2 treatment. The electrical conductivity and pH were maintained between 1.5 – 2.0 mS/cm and 5.5-6.5 respectively.Chemicals used to prepare 1000l of commercially available Albert's solution (Unipower private limited) is given in Table 2.

Table 2: Chemicals present in Albert's solution

Chemical compound	Weight in grams (g) per kilogram (kg) of compound (g/kg)
Potassium Nitrate	450
Calcium Nitrate	1000
Magnesium Sulphate	87.5
Anhydrous Iron EDTA	10
Zinc EDTA	2
Boric Acid	0.4
Manganese EDTA	2
Copper EDTA	1.5
Mono Potassium Phosphate	360
Sodium Molybdate	0.1

2.7 Rearing of Fish

Thirty fish fingerlings of each species; Tilapia (*Oreochromis mossambicus*), Catla (*Catlacatla*) and Common Carp (*Cyprinus carpio*) were used in this experiment. Fish fingerlings (nearly 5 cm) were allowed to acclimatize to the culture conditions for 3 weeks before the trial began. Fish were fed with rice bran, according to 3% of its body weight/day (Food and Agriculture Organization, 2023). Then the amount of feed given was increased with the same amount for all treatments according to their palatability (Celikkale, 1994).

2.8 Data collection and analysis

The composition, temperature (^{0}C), pH and electrical conductivity (mS/cm) of the nutrient solutions were measured and, the body weight (g), initial and final stocking density (g/m^3) and mortality percentage of fish were recorded. The plant growth and yield parameters measured were plant height (cm), number of leaves, canopy diameter (cm),root length (cm), fresh weight of plants, leaves and roots (g), dry weight of leaves and roots (g) and yield (tons/ha).Analysis of variance (ANOVA) was performed using SAS statistical software package and mean comparison was done using Duncan's Multiple Range Test (DMRT) at 5% significance level.

3 RESULTS AND DISCUSSION

3.1 Nutrient Solution

3.1.1 Nutrient Composition

The composition (Nitrogen [N], Phosphorus [P] and Potassium [K])of the nutrient solutions used in the experiment is given in Table 3. Based on the measurements, it is clear that the N,P and K content in Albert's solution has not changed throughout the experiment but the nutrients in fish waste water increased at two weeks intervals.

Table 3: Nutrient composition in nutrient solutions weeks after establishment in hydroponic system

Treatment	**2nd week**			**4th week**			**6th week**		
	N	P	K	N	P	K	N	P	K
T1	-	-	-	-	-	-	-	-	-
T2	135	70	288	135	70	288	135	70	288
T3	3.28	3.28	2.94	6.52	4.25	3.88	11.59	9.38	6.45
T4	4.25	2.56	2.45	7.58	4.95	4.52	12.48	8.93	6.88
T5	4.56	4.53	3.56	7.38	9.58	5.84	16.14	12.35	9.12

<u>3.1.2. Nutrient Increment in Fish Waste Water</u>

It is clear from Figure 1,2 and 3 that the N, P and K contents of fish waste water had increased every two weeks in all fish species. Amount of feed provided was increased according to their body weight in every two weeks' time in this experiment. Due to the increase in the amount of feed, the nutrient content in the waste water also may have increased. Rahman (2010) reported that in an aquaculture system, the nutrient load increases in proportion to the feeding rate. However, the increment of N, P and K levels were higher in waste water from Tilapia tank compared to the other two fish waste solutions. The body weight increment of Tilapia was also higher than other species (Figure 10), which might have resulted in a higher nutrient content in its waste water. According to Childress & Vincent (2013) and Johanson (2009), Tilapia grows quickly, as it has a good feed conversion rate and produces high levels of ammonia, which is good for maintaining adequate nutrient levels for the aquaponic system. In addition, the amount of nitrogenous waste produced by fish is dependent upon the protein content of their feed. So, quality feed supplement is very important as the growth and quality of plants depend the nutrient content in fish waste water (Lennard, 2004).

In an aquaponic system, the mix and concentrations of various nutrients are determined by critical factors such as feed rate and feed quality. Different diets are appropriate for different growth stages of fish. Pre-adult fish need 40-50 % of crude protein (Fitzsimmons & Posadas, 1997). In this experiment commonly available rice bran was used as a feed for fish. However, it contained only 9% of crude protein (Table 4) which is not sufficient for the required growth of fish. It should have been the reason for the low amount of nutrients in fish waste water (Table 3) and low weight gained in fish (Figure 10).

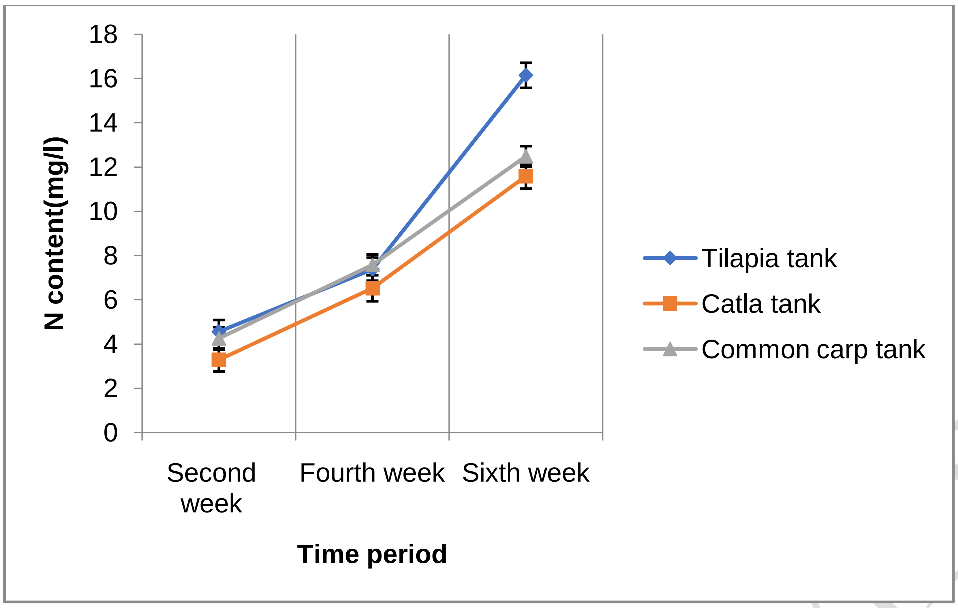

Fig.1: Nitrogen content (mg/L) in fish waste water

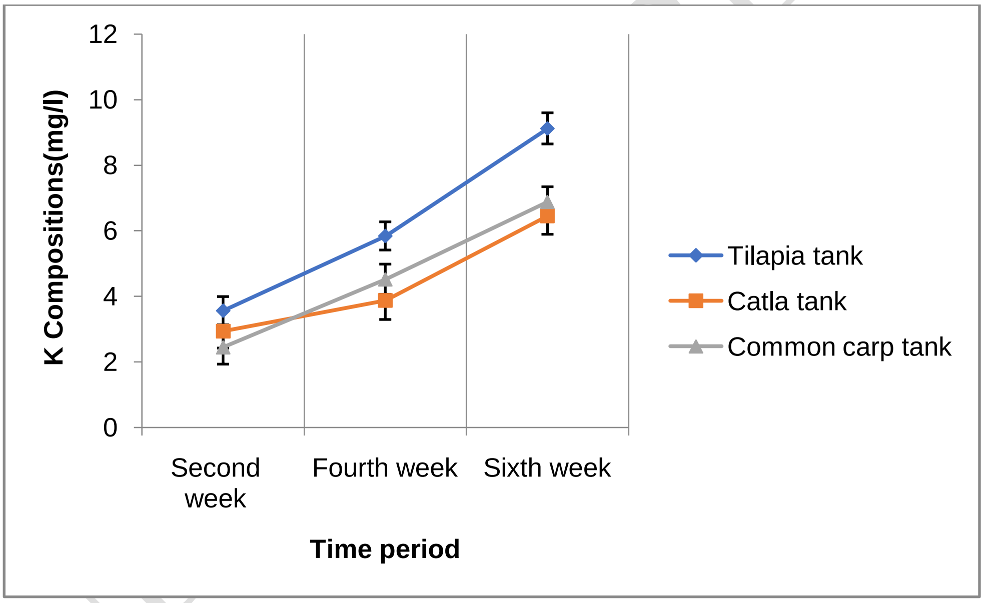

Fig.2: Potassium content (mg/L) in fish waste water

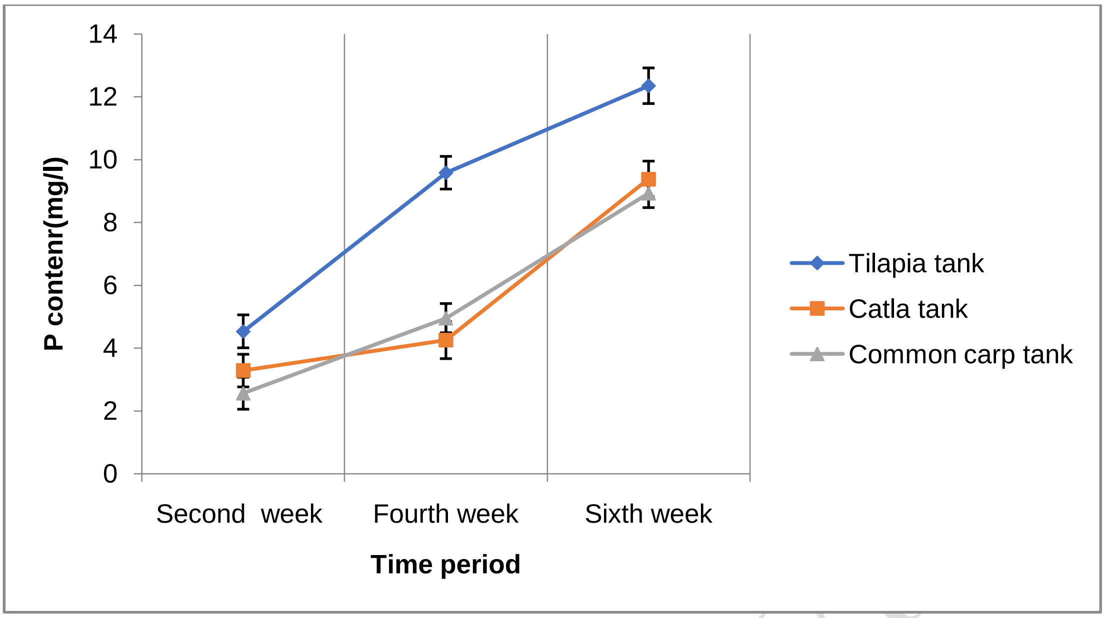

Fig.3: Nitrogen content (mg/L) in fish waste water

Table 4: Nutrient composition in rice bran

Proximate composition	Percentage (%)
Crude protein	9%
Lipid	9.8%

3.1.3. Temperature

As shown in Figure 4, the temperature ranged between 17.9^{0}C – 25.9^{0}C in all the nutrient solutions throughout the experimental period. A minimum temperature was recorded in each day in Albert's solution compared to the other solutions. The higher temperatures recorded in fish waste water might have been due to the high microbial activity which led to the production of higher energy in them (University of Minnesota, 2006). One of such microbial processes occurring in fish waste water is nitrification. Fish release ammonia (NH_3) when exchanging oxygen (O_2) and carbon dioxide (CO_2) during their respiration process. *Nitrosomonas* bacteria use this ammonia to make nitrate (NO_3^-) and nitrite (NO_2^-), which the plant uses to thrive, in order to maintain the health of fish. These processes possibly might have led to production of energy (Ochmanski, 2013) in fish waste water.

High root temperatures will also affect the growth of lettuce in deep flow hydroponics. Thompson et al. (1998) showed that when the root zone temperature (nutrient solution) was kept below 20°C, yield of lettuce was increased. However, since the temperature in Albert's Solution (17.8°C -24°C) was lower than the other solutions (18.3 °C – 25.9°C), it might have produced a higher yield

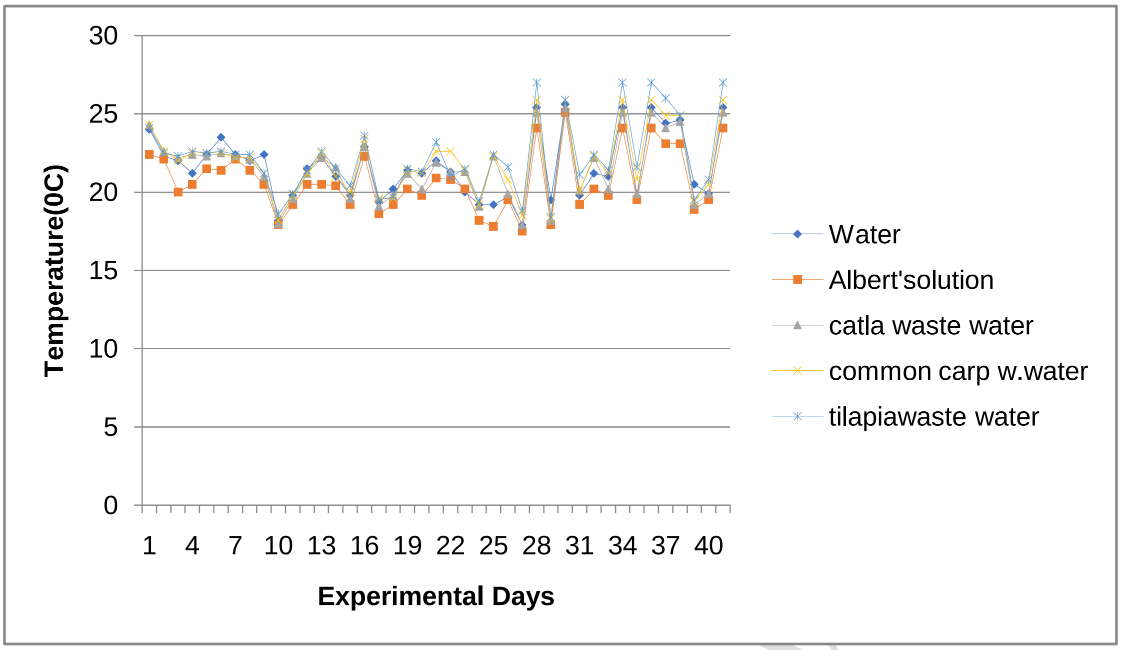

Fig.4: Variation of temperature in nutrient solutions during the experimental period.

3.1.4 pH

The pH of the nutrient solutions used in the experiment is given in Figure 5. According to the measurements, the pH values of all fish waste solutions have decreased over the experimental period. Possible reasons for this could be the formation of carbonic acid due to the dissolution of CO_2 (produced by respiration of fish) in the tanks caused by the action of nitrifying bacteria, and also from the breakdown of faeces and uneaten food by bacteria to form other organic acids (Randall,1998). Generally, the pH value of water is considered as 5.5 to 7.5 (Peck, 1990) and it is clear that this level has not changed throughout the experiment. The pH in the Albert's solution was maintained between 5.5-6.5 during the experiment. According to Resh (2001), lettuce grows best and uptake nutrients at a lower pH (5.5 - 6.5) in hydroponic systems. The pH has ranged between 5.5-6.6 in all nutrient solutions throughout the experimental period. Therefore, pH may not have affected growth and yield of lettuce.

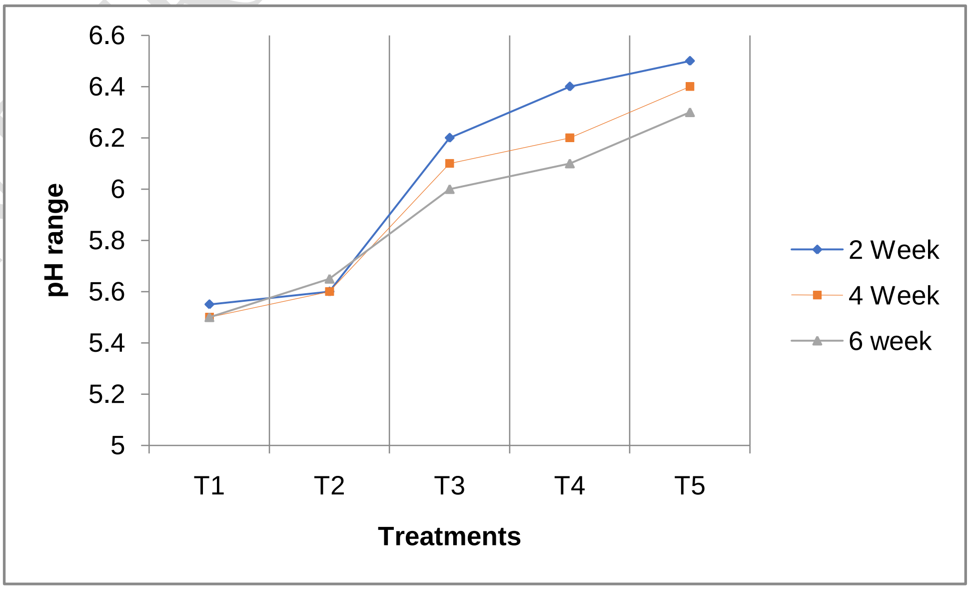

Fig.5: Variation of pH in nutrient solutions during the experimental period

3.1.5 Electrical Conductivity

The Electrical Conductivity (EC) of the solutions used in the experiment is given in Figure 6. According to the measurements, the EC was carefully maintained according to the standard levels for hydroponics in Albert's solution (1.5 – 2.0 mS/cm). A slight increment in EC was observed week by week in T3, T4 and T5, and the reason for this could be that certain nutrients dissolved in fish waste water might not have been removed in the aquaponic system at the rate at which they were being produced. According to Resh (2001), EC levels ranging between 1-2 mS / cm is most suitable for hydroponic lettuceproduction. However, in the present study, this level was available only T2 (Albert's solution) which might have been the reason for showing better growth parameters of lettuce.

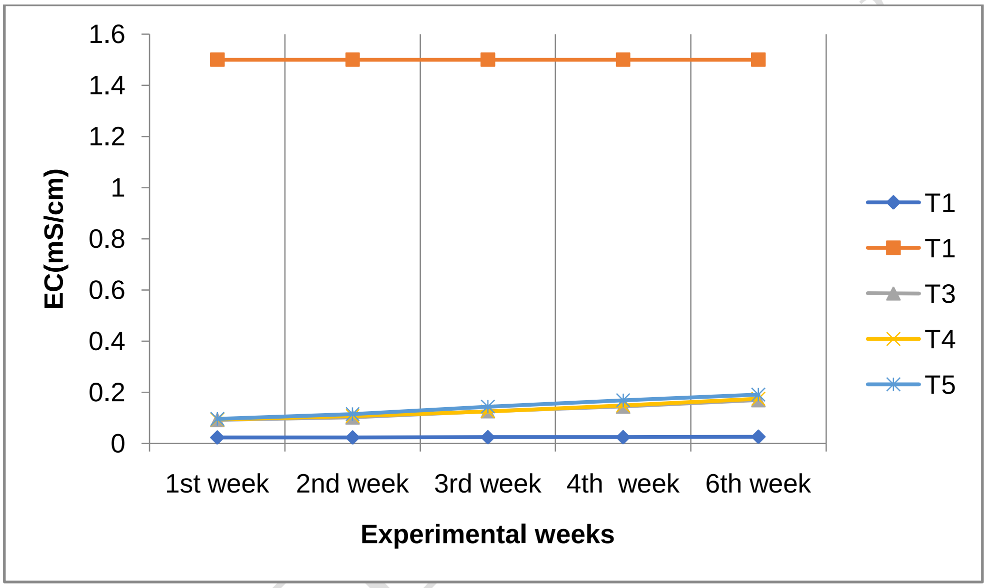

Fig.6: Increment of EC in nutrient solutions during the experimental period

3.2 Plant growth parameters

3.2.1 Plant height

According to the analyzed results shown in Table 5, the highest plant height was observed in plants grown with Albert's solution (T2) and lowest plant height was observed in plants grown with water (T1) from 2ndweek to 6thweek after establishment of lettuce in the aquaponic system. The plants grown in T3, T4 and T5 showed higher plant heights than that of water (T1) in any week. There was no significant difference among fish waste solution treated plants from 2nd week to 6thweek after establishment in aquaponic system.

Table 5: Effect of nutrient solutions on the plant height of lettuce

Treatment	Initial plant height(cm)	Plant height(cm) at weeks after establishment in hydroponic system		
		2nd week	4th week	6th week
T1	5.68±0.13^{a}	5.72±0.21^{c}	5.75±0.21^{c}	5.80±0.20^{c}
T2	5.65±0.19^{a}	6.74±0.13^{a}	7.00±0.35^{a}	12.27±0.47^{a}
T3	5.63±0.11^{a}	6.55±0.26^{b}	6.81±0.11^{b}	6.93±0.40^{b}

T4	5.65±0.11^{a}	6.50±0.21^{b}	6.82±0.23^{b}	6.96±0.25^{b}
T5	5.66±0.13^{a}	6.63±0.22^{ab}	6.85±0.19^{ab}	7.29±0.16^{b}

According to Tukey's Test, means in the same column followed by dissimilar letter/s in superscripts indicate significant difference at 0.05 level of probability.

3.2.2 Number of Leaves

Data pertaining to the number of leaves shown in Table 6reveals that during the 4th and 6th week after establishment of lettuce in the aquaponic system the highest number of leaves was observed in Albert's solution treated plants (T2) and the lowest number of leaves was observed in water treated plants. There was no significant difference among fish waste solution treated plants. In addition, the number of leaves was higher in fish waste water treated plants (T3, T4 and T5) than water treated plants (T1). During the 6th week, among the fish waste solutions treated plants, the highest number of leaves was observed in plants treated with waste solution from Tilapia tank (T5).

Table 6: Effect of nutrient solutions on the number of leaves of lettuce

Treatment	Initial number of leaves	Number of leaves at weeks after establishment in hydroponic system	
		4th week	6th week
T1	4.15±0.21^{a}	4.33±0.25^{c}	4.35±0.31^{d}
T2	4.00±0.16^{a}	6.58±0.25^{a}	12.25±0.19^{a}
T3	4.00±0.36^{a}	5.45±0.25^{b}	5.87±0.16^{c}
T4	4.00±0.31^{a}	5.50±0.09^{b}	5.95±0.16^{c}
T5	4.00±0.28^{a}	5.60±0.08^{b}	7.75±0.28^{b}

According to Tukey's Test, means in the same column followed by dissimilar letter/s in superscripts indicate significant difference at 0.05 level of probability.

3.2.3 Canopy diameter

As shown in Table 7, ANOVA resultsfrom 2nd week to 6thweek after establishment of lettuce in the aquaponic system,a higher canopy diameter was recorded in Albert's solution (T2) treated plants and lowest canopy diameter was recorded in water (T1) treated plants. However, canopy diameter was high in fish waste solution treated plants (T3, T4, and T5) than the water treated plants (T1). There was nosignificant difference observed among fish waste solution treated plants (T3, T4, and T5) from 2ndweek to 6th week after establishment in aquaponic system.

Table 7: Effect of nutrient solutions on the canopy diameter of lettuce

Treatment	Initial canopy diameter(cm)	Canopy diameter (cm) at weeks after establishment in hydroponic system		
		2nd week	4th week	6th week
T1	6.75±0.53^{a}	7.00±0.57^{c}	7.25±0.55^{c}	7.37±0.54^{c}
T2	6.73±0. 91^{a}	8.18±0.23^{a}	10.84±0.96^{a}	14.80±0.52^{a}
T3	6.63±0. 73^{a}	7.50±0.45^{b}	8.42±0.39^{b}	8.99±0.19^{b}
T4	6.67±0. 14^{a}	7.84±0.46^{b}	8.53±0.54^{b}	9.05±0.61^{b}
T5	6.72±0. 83^{a}	7.91±0.24^{b}	8.92±0.05^{b}	9.68±0.77^{b}

According to Tukey's Test, means in the same column followed by dissimilar letter/s in superscripts indicate significant difference at 0.05 level of probability.

3.2.4. Root length

According to the analyzed results shown in Table 8, at 2 weeks after establishment of lettuce in the aquaponic system, the highest root length was observed in Albert's solution treated plants (T2) followed by plants treated from waste solution from Tilapia tank (T3, T4 and T5). There was no significant difference in the root length among T1, T3 and T4.During 4th week and 6th week after establishment, higher root lengths were observed in Albert's solution treated plants (T2) and the lowest root length was observed water treated plants (T1).However, the root length was high in fish waste solution treated plants (T3, T4 and T5) than water treated plants (T1). Although statistically insignificant, among the fish waste solutions treated plants, a higher root length was observed in plants treated from waste solution from Tilapia tank (T5) compared to the Catla tank (T3) and Common Carp tank (T4).

The higher root length observed in Albert's solution treated plants (T2) might have occurred due to the higher and balanced nutrient content in Albert's solution compared to the other treatments (Table 3). It is a well-known fact that, in addition to being a component of many important organic substances such amino acids, proteins, coenzymes, nucleic acids, and chlorophyll, nitrogen is the most important nutrient that promotes plant growth and elongation (Resh, 2001). Resh (1995) reported that 165ppm of nitrogen concentration is needed for lettuce production in aquaponic systems. However, the nitrogen concentration of fish waste water solutions did not rise above 16.14 ppm during this experiment. It may be one reason for the highest plant height, canopy diameter, number of leaves and root length recorded in Albert's solution treated plants.

Poor root lengths and lower plant heights were observed in T1, T3, T4 and T5 when compared with Albert's solution (T2), which may be due to the phosphorus deficiency in those solutions. This result is in accordance with Jones 1997; Salisbury & Ross 1992 who reported a generally stunted growth and poor root length in lettuce plants due to phosphorus deficiency. Resh (1995) also stated that a phosphorus concentration of 50ppm is needed for lettuce production in aquaponic systems. However, since the phosphorus concentration of fish waste water solutions did not rise above 12.35ppm during this experiment the growth parameters of lettuce might have been showing lower values in this experiment.

When comparing T3, T4 and T5, at 6thweek after establishment in the aquaponic system,higher N, P and K levels were observed in waste water solution from Tilapia tank (T5). It could be one of the reasons for a higher number of leaves and root length in plants treated with waste water from Tilapia tank than others.

Table 8: Effect of nutrient solutions on the root length of lettuce

	Initial root	Root length(cm) at weeks after

Treatment	length (cm)	establishment in hydroponic system		
		2nd week	4th week	6th week
T1	3.25±0.10[a]	3.39±0.16[c]	3.76±0.23[d]	4.13±0.20[d]
T2	3.33±0.30[a]	8.16±0.58[a]	12.40±0.56[a]	15.04±0.41[a]
T3	3.42±0.17[a]	3.48±0.90[c]	4.72±0.14[c]	5.47±0.14[c]
T4	3.35±0.75[a]	3.74±0.40[c]	5.40±0.85[c]	5.97±0.76[c]
T5	3.30±0.49[a]	5.51±0.32[b]	9.59±0.29[b]	12.42±0.10[b]

According to Tukey's Test, means in the same column followed by dissimilar letter/s in superscripts indicate significant difference at 0.05 level of probability.

3.2.5Fresh weight of plant, leaves and roots

According to the results shown in Figure 7, the highest plant, leaf and root fresh weight were recorded in Albert's solution treated plants (T2) followed by plants treated with waste solution from Tilapia tank (T5). The lowest plant, leaf and root fresh weight were observed in plants grown in water (T1).

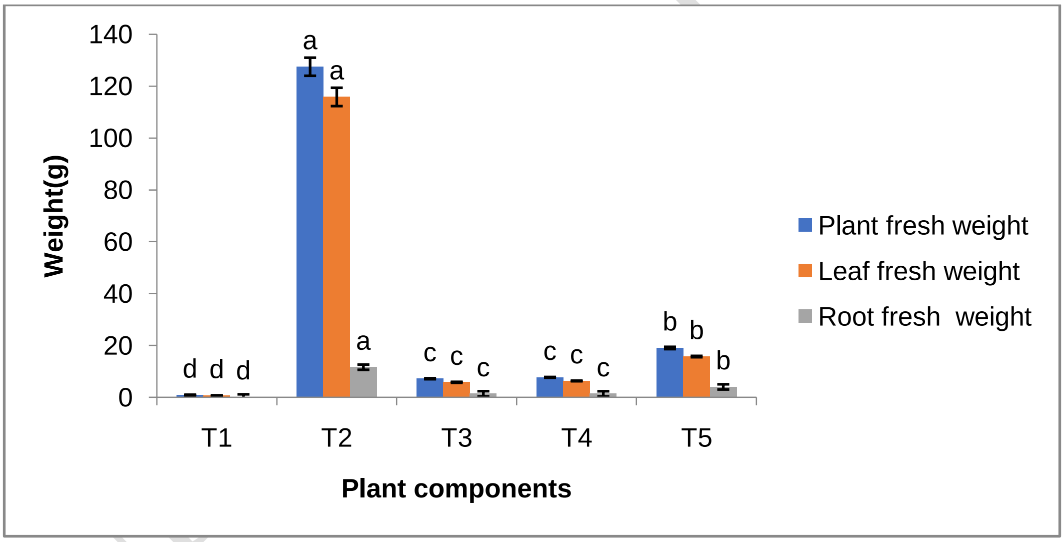

Fig.7: Mean plant, leaf and root fresh weight per plant at six weeks after planting in hydroponic system.

3.2.6Dry weight of leaves and roots

As shown in Figure 8, the highest dry matter contents of leaves and roots were observed in plants grown in Albert's solution (T2) followed by plants treated with waste water from Tilapia tank (T5). Lowest dry matter content of leaves and roots were observed in plants grown in water (T1).

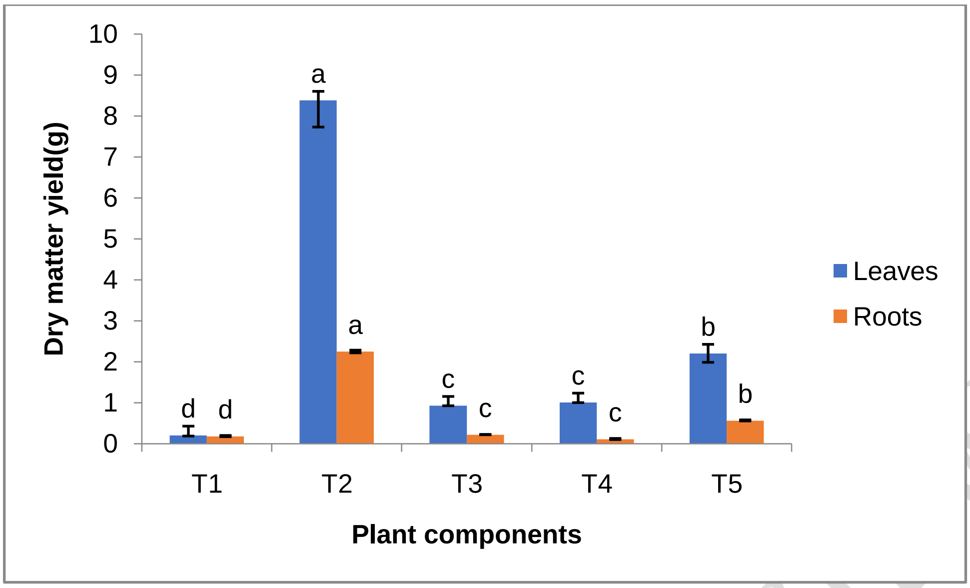

Fig.8: Dry weight of leaves and roots of lettuce at six weeks after planting in hydroponic system.

3.2.7 Yield

According to the results shown in Figure 9, the total yield was significantly higher in plants grown in Albert's solution (T2), followed by plants grown in waste solution from Tilapia tank (T5). The lowest yield was recorded in the plants grown with water (T1). It is possible to describe the yield of the plants in terms of the dry matter production per plant. The dry matter production of a crop is positively correlated with the photosynthesis of a plant (Catherine, 2004). Iron is an essential nutrient required for photosynthesis and respiration in plants (Resh, 2001). Generally, iron concentration in aquaponic waste water is inadequate to support plant growth and therefore iron has to be supplemented to a concentration of 2 mg/l (Rakocy et al., 2006). In this experiment, although lettuce plants were not treated with an external source of iron, the Albert's solution used contained 0.065% of chelated iron. It should be the reason for the highest dry matter production and total yield in plants grown with Albert's solution (T2) than fish waste water treated plants (T3, T4 and T5).

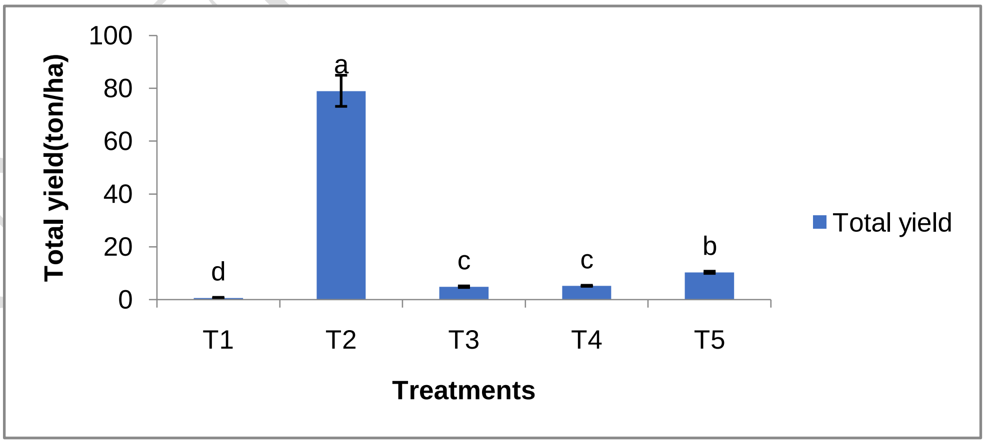

Fig.9: Total yield of lettuce grown in hydroponic system with different nutrient solutions

Macro nutrients play an important role in crop development and yield (Sekhon, 2003). Authors such as Resh (1995 and 2006) suggested suitable nutrient concentrations such as 165ppm nitrogen, 210ppm potassium and 50ppm phosphorus for lettuce production in aquaponic systems. It is clear from the Figures 1,2 and 3 that the nitrogen, phosphorus and potassium concentration of fish waste water solutions (T3, T4 and T5) did not rise above 16.14 ppm, 12.25ppm and 9.12ppm respectively during this experiment. It might be one of the main reasons for the reduction of total yield in plants grown with fish waste water solutions (T3, T4 and T5) than Albert's solution treated plants (T1). According to Table 3, there is a prominent difference in nitrogen, potassium and phosphorus levels in Albert's solution (T2) and fish waste water solutions (T3, T4 and T5). The significant differences observed in growth parameters and yield parameters of lettuce could be due to the adequate nutrient supply from Albert's solution (T2) when compared to fish waste water (T3, T4 and T5).

3.3 Fish-related parameters

3.3.1 Body weight

It is clear from Figure 10 that the increment of body weight was higher in Tilapia fish than the other two fish species (Catla and Common Carp).

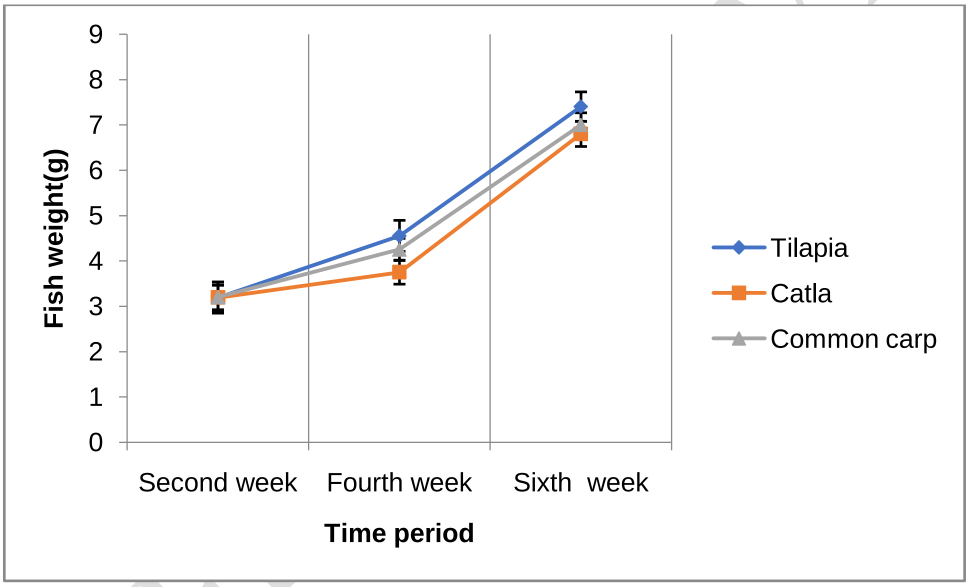

Fig.10: Body weight gaining of fish species during six weeks period

3.3.2 Initial and Final Stocking Density

Figure 11 shows that the body weight and final stocking density was recorded to be highest in Tilapia fish than the other two fish species (Catla and Common Carp). Tilapia is a popular fish species for aquaponic recirculating systems because of their resilience, high growth rate and low protein requirements. Compared to other fish species grown in aquaculture systems, Tilapia being omnivores feed on a wide range of organisms and have a relatively low protein need(Fitzsimmons, 2006). It might have been the reason for achieving the highest body weight and highest final stocking density in Tilapia fish species.

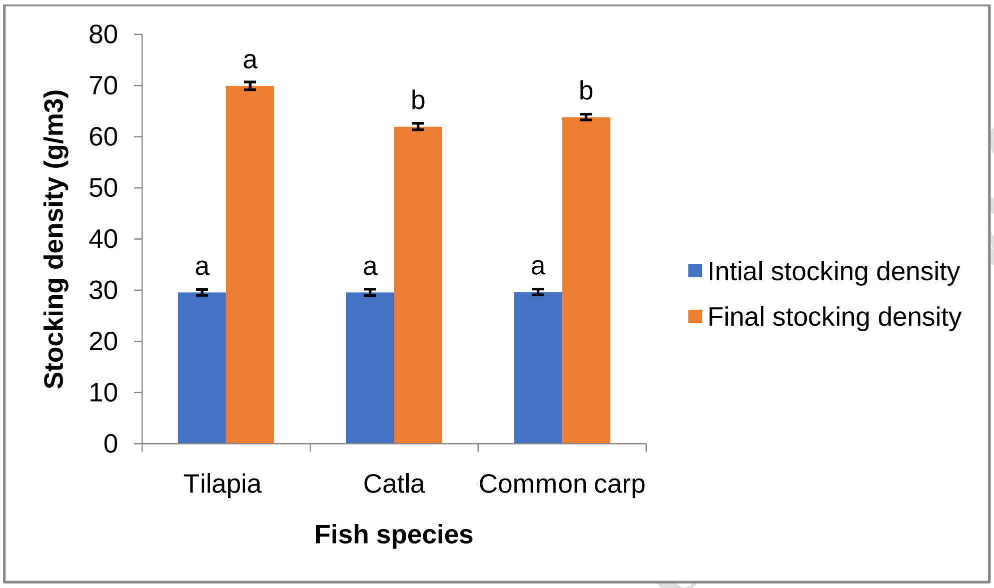

Fig.11: Initial stoking density and final stocking density of fish species during six weeks period.

3.3.3 Mortality Percentage

It is clear from Figure 12 that a higher mortality percentage was recorded in Catla fish species. During the experiment six of Catla fish were found dead due to unfavorable environmental conditions. Ayappan (2001) reported that Catla species can best survive at water temperatures between 25-32°C. However, in the present experiment, the temperature in Catla waste water

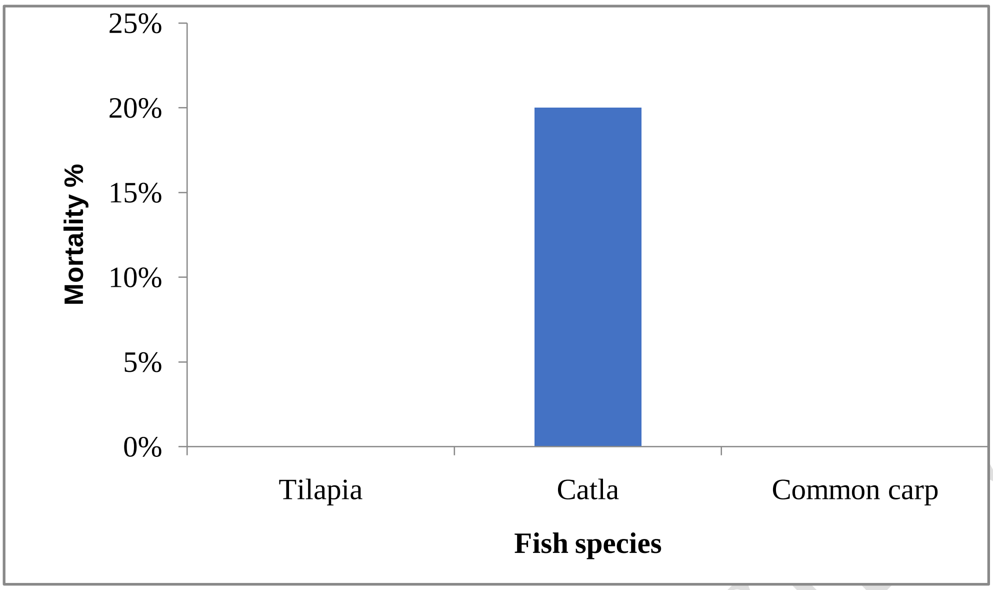

Fig.12: Mortality percentage of fish species

4 CONCLUSION

When considering the overall results of the experiment, Albert's solution showed the best growth and yield performance of lettuce compared to the other treatments, due to the higher nutrient content present in it. However, the main drawbacks of Albert's solution are its high cost and the environmental pollution it causes leading to human health issues.Followed by the Albert's solution, the best performance was shown by lettuce plants provided withTilapia fish waste. Unlike inorganic fertilizer, the usage of fish waste water in aquaponics is not harmful to the environment. In addition, two types of organic yield can be obtained sustainably from an aquaponic system, i.e. crop yield and fish yield. However, the fish waste solutions used in this experiment did not sufficiently fulfill the nutrient requirement of the lettuce plants because the Nitrogen (N), Phosphorus (P) and Potassium (K), which are essential for the growth of plants were found to be limited in fish waste water due to the age of fish used (fingerlings). Therefore, these fish waste water solutions should be improved by increasing the quality of feed and selecting fish within a suitable age group, as aquaponics will be a promising technique for crop production in future.

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