

Utilization of effluent fish farms in tomato cultivation



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ABSTRACT

The main objective of this research is to study to which extent the content of nutrients in water farming is sufficient for growing tomato plants. The obtained results indicated that the nutrients consumption increased with increasing the flow rate. The root and shoot length increased with increasing effluent flow rate, when the effluent flow rate increased from 4.0 to 6.0 L h⁻¹, the length of root and shoot significantly increased from 50.33 to 55.33 and 149.33 to 191.33 cm, respectively, at the end of growing period. The fresh and dry mass of shoot significantly increased from 998.01 to 1372.10 and 83.71 to 275.09 g plant⁻¹, respectively, with increasing flow rate from 4.0 to 6.0 L h⁻¹. The fresh and dry mass of root significantly increased from 388.07 to 423.91 and 30.37 to 38.98 g plant⁻¹, respectively, with increasing flow rate from 4.0 to 6.0 L h⁻¹. The fruit yield significantly increased from 1.06 to 1.37 kg plant⁻¹ with increasing flow rate from 4.0 to 6.0 L h⁻¹. The fruit mass and number of fruits increased from 75.07 to 81.32 g and 14.12 to 16.85 with increasing flow rate from 4.0 to 6.0 L h⁻¹. The water use efficiency increased from 5.54 to 7.16 kg m⁻³ with increasing flow rate from 4.0 to 6.0 L h⁻¹. Using the effluent fish farm could save fertilizers which equivalents 0.13 LE kg⁻¹ fruits (130 LE t⁻¹ fruits). Besides it is considered as an organic product which is safe for the human health.

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1. Introduction

Population of Egypt is gradually increasing and there is a necessity to find out new techniques to reduce the gap between population needs and agricultural production. One of the new techniques called “aquaponics” is which we can utilize the outputs of fish farming in growing vegetables, i.e., lettuce, cucumber, tomato, cabbage and so on. In this technique a minimum requirements of nutrients could be used, furthermore removal the fish feces (Khater, 2006).

Aquaponics is the integration of aquaculture (fish farming) and hydroponics (growing plants without soil). In aquaponic system the fish consume food and excrete waste primarily in the form of ammonia. Bacteria convert the ammonia to nitrite and then to nitrate (Diver, 2000; Bromes, 2002; Rakocy, 2002; Selock, 2003; Lee, 2004; Okimoto, 2004; Karen, 2005; Nelson, 2006a,b,c, 2008; Graber and Junge, 2009).

Aquaponics has several advantages over other recirculating aquaculture systems and hydroponic systems that use inorganic nutrient solutions. The hydroponic component serves as a biofilter,

and therefore a separate biofilter is not needed as in other recirculating systems. Aquaponic systems have the only biofilter that generates income, which is obtained from the sale of hydroponic produce such as vegetables, herbs and flowers (Rakocy and Hargreaves, 1993).

Aquaponic system is one of the economical solutions for getting benefits from the water-waste from the fish farms as it save nutrients and produce fresh vegetables. With using this system successively its cost will be decreased and became more economic. The produced plants via this system considered as an organic product which is more safe for human consumption (Khater and Ali, 2015).

Small proportion of ammonia is toxic to fish, when as nitrate is not toxic to fish. If nitrate increased over a specific limit it will be toxic to fish eaters (human being) and cause nitrate pollution and the eaters will suffer from methemoglobinemia disease. The blood of the affected people became brown and will not be able to carry oxygen to the rest of human organs (Tucker and Boyd, 1985). To avoid this problem in aquaculture, part of water should be discharged daily and add fresh water instead. Another solution to this problem is establishing hydroponic system attached to the aquaculture and cultivates plants in the hydroponics in order to save discharged-water and gets use of existing nitrate.

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Benefits of aquaponics are conservation of water resources and plant nutrients, intensive production of fish protein and reduced operating costs relative to either system in isolation. Water consumption in integrated systems including tilapia production is less than 1% of the required in pond culture to produce equivalent yields (Rakocy, 2002).

Plant cultivars with high biomass production may have a high potential for being used in integrated water treatment and plant production system. The highly productive hybrid Napier grass cultivar, *Pennisetum purpureum* × *Pennisetum americanum* cv. Pakchong₁, may be a candidate species for being used in such systems. We studied the effects of inorganic nitrogen form (NH_4^+ , NH_4NO_3 or NO_3^-) on growth, morphology, N uptake, water content and mineral allocation in this species under hydroponic conditions at equimolar concentrations ($500 \mu\text{mol NL}^{-1}$). Generally, the N-form significantly affected growth, biomass allocation and tissue nutrient and mineral composition of the plants. The hybrid Napier grass grew better on NH_4^+ compared to NO_3^- , and the plants supplied with NH_4^+ contained three times more chlorophylls than plants supplied with NO_3^- alone or NO_3^- combined with NH_4^+ . The morphology of the plants was, however, not affected by N source, except for the shoot to root ratio, which was lower in NH_4^+ -fed plants. The relative water content of the leaves was lowest in the NH_4^+ -fed plants, but the transpiration rate was not affected, indicating that NH_4^+ nutrition and the associated low tissue concentration of K had negative effects on the water use efficiency of the plants (Jampeetong et al., 2014).

Rana et al. (2011) studied revealed that $\text{PO}_4\text{-P}$ was removed by 58.14–74.83% with maximum removal at 50% wastewater. More than 75% removal of $\text{NO}_3\text{-N}$ was observed in all treatments. Both COD and BOD were reclaimed highest at 100% wastewater by 61.38% and 72.03%, respectively. Ammonium-N concentration was subsided below the toxic level in all the treatments. The population of coliform bacteria (*Escherichia coli*) was reduced to 91.10–92.18% with maximum efficiency at 100% wastewater. Growth performance was observed relatively better at 100% wastewater. Crop production as the value addition of this technology was also recorded maximum at 100% wastewater. The bioaccumulation of Cd and Ni in tomato crop was far below the threshold level, but the bioaccumulation of Lead (Pb) and Crom (Cr) was above the safe level by 80 times and 660 times, respectively. The aquaponically reclaimed water can be reused in agriculture, aquaculture and industries.

Yang et al. (2015) studied a hydroponic system was applied as the final treatment stage of source-separated human urine after urea hydrolysis, induced-struvite precipitation and ammonia stripping in tropical conditions (Singapore). The results showed that water spinach grew efficiently in the pretreated urine with 1:50 dilution ratio at the growth rate 0.68 cm day^{-1} , leaf number $2.27 \text{ pieces day}^{-1}$, shoot dry mass 0.33 g , water content 93.86%, and nitrogen and potassium conversion rate 0.46 and 0.51 mg/mg , respectively. This hydroponic system removed 58–66% chemical oxygen demand (COD), 41–49% total nitrogen (TN) and up to 47% total suspended solid (TSS), indicating sufficient urine stream polishing. Nitrification was observed when COD reduced by 60%, possibly because of oxygen competition between nitrobacteria for nitrification and microbes for COD degradation. The kinetic study revealed that zero-order model provided best fitting for COD and ammonia-nitrogen ($\text{NH}_4^+\text{-N}$) removal, while second-order model was more suitable for TN removal.

Tomato is one of the most important crops worldwide, because tomato is the second most important vegetable in the world after potato, with an annual production of 161.8 million tons in 2012. Tomato is one of the most important economic vegetable crops, practiced by the Egyptian farmers. The total cultivated area of

tomato is about 454,800 Faddens and total production of tomato in 2012 was 8.6 million tons (FAO, 2012).

Due to gradually increasing of production costs, it is required to maximize the utilization of available resources. Nutrients in the recycling water is considered one of these resources, therefore, the main objective of this investigation was to study to which extent the content of nutrients in water discharged from fish farms is sufficient for growing tomato plants, in order to reduce the using of chemical fertilizers and increase the water use efficiency, consequently increase the profits of production.

2. Materials and methods

The experiment was carried out at National Institute of Oceanography and Fisheries (NIOF) El-Knater El-Khiria, Kalubia Governorate, Egypt. During the period of March to June, 2014 season.

2.1. System description

Fig. 1 illustrates the experimental setup. It shows the recirculating aquaculture system which consists of fish tanks, bio-sump tank, hydroponic units and pumps under two green-houses.

The system consists of five rectangular concrete tanks that used for fish culture. Dimensions of each tank are 8 m long, 5 m wide and 1.5 m high. The water volume in each tank was 40 m^3 . Each tank has an inlet pipe and two types of outlets pipe. The inlet pipes for adding fresh water to fish tank, two types of outlets for one of them is a mechanical spillway which carries the normal expected water flow from the tank and can be designed to either partially or completely drain the tank to facilitate harvest. The second one is an emergency spillway which used to remove the exceed water capacity of tank.

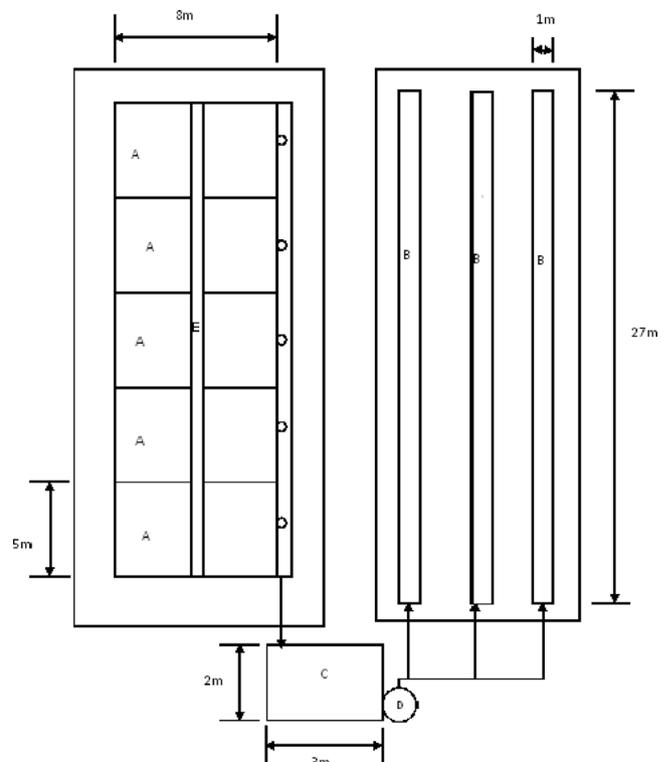


Fig. 1. The experimental setup. Fish tanks (A) hydroponic units, (B) bio-sump tank, (C) pump, (D) path way, (E).

The rectangular concrete tank was used in this system for removal solid wastes. Dimensions of tank are 3 m long, 2 m wide and 0.5 m high. The water volume used in each tank was 2.4 m³. Polyethylene sheets were used as a media for solids removal and carry bacteria in the system to improve the water quality.

The hydroponic units in this study consists of three gullies which made from concrete, lined by plastic sheet and covered with foam boards to support the plants. Dimensions of this tank are 27 m long, 1.0 m wide and 0.5 m high with row spacing of 50 cm.

The solution was pumped from the tank to the upper ends of the gullies. Small tubes were used to supply each gully with water discharged of the fish farm in a closed system.

2.2. Tomato plants

Tomato seeds were sown in the plastic cups (7 cm diameter and 7 cm height) filled with peatmoss. The cups were irrigated daily using water with nutrient solution was prepared manually dissolving appropriate amounts of Ca(NO₃)₂, KNO₃, K₂SO₄, KH₂PO₄, MgSO₄ and chelates for trace elements into preacidified ground-water, pH was adjusted to 6.0–7.0 after salt addition. Two weeks old tomato seedlings were planted in the experimental trays according to Roosta and Hamidpour (2011).

2.3. Measurements

Water samples were taken, at inlet and outlet of the hydroponic units for measuring Ammonia (NH₃), Nitrite (NO₂), Nitrate (NO₃), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg). Ammonia (NH₃), Nitrite (NO₂) and Phosphorus (P) measured by a Spekol 11 (Model SPEKOL 11—Range 0. 1–1000 concentration ± 1 nm λ, UK). Potassium (K) measured by flame photometer (Model Jenway PFP7—Range 0. 1–999.9 ppm ± 0.2 ppm, USA). Calcium (Ca) and Magnesium (Mg) measured by using disodium versenate method as described by Black (1965). Nitrate (NO₃-N) content was measured by using salicylic acid as described by Chapman and Partt (1961).

Three tomato plants representing each replicate every month were taken as recommended by (Resh, 1981). Root length, stem diameter, shoot length, number of leaves, shoot and root dry weight were determined. Fresh shoots and roots of tomato plants were weighed and placed in drying oven with circulating air at 65 °C for 48 h until constant weight was reached. Fruit yield, fruit weight and number of fruits per plant were also determined at the end of the experiment.

2.4. Calculations

The nutrient consumption was calculated as the differences between the nutrient at inlet and outlet of hydroponic units by the following formula:

$$NC = \frac{NC_{in} - NC_{out}}{\text{Number of plants}} \times Q \quad (1)$$

where:-

NC is the nutrient consumption, mg h⁻¹

NC_{in} is the nutrient at inlet of the hydroponic unit, mg L⁻¹

NC_{out} is the nutrient at outlet of the hydroponic unit, mg L⁻¹

Q is the discharge, L h⁻¹

Water use efficiency (WUE) was determined by the following formula:

$$WUE = \frac{\text{Fruit Yeild}}{\text{Crop Water Uptake}}$$

Crop water uptake was modelled as a function of leaf area index (LAI) and daily radiation (DR) intercepted by the crop canopy:

$$CWU = b_1 \times \left(1 - e^{-k \cdot LAI}\right) \times \frac{DR}{\lambda} + b_2 \quad (3)$$

where:-

CWU is the crop water uptake

b₁ and b₂ are the empirical constants

k is the canopy light extinction coefficient

λ is the latent heat of water vaporization.

Leaf area index was assumed to obey a sigmoid function of accumulated thermal time (expressed as growing degree days, GDD):

$$LAI = a_1 + \frac{(a_2 - a_1)}{1 + e^{(a - GDD/a_4)}}$$

where:-

a₁, a₂, a₃ and a₄ are the regression coefficients.

The parameters used in the equations that were obtained from the literature are listed in Table 1.

2.5. Statistical analysis

The statistical analysis for the data obtained was done according to Snedecor and Cochran (1980) and the treatments were compared using Least Significant Differences (LSD) test at 99% confidence level (Gomez, 1984).

3. Results and discussion

3.1. Nutrients consumption

Nitrogen, phosphorus, potassium, calcium and magnesium consumption rate were determined is during the growth period of tomato at different flow rate. Any removal of nutrients from the solution can be equated with uptake by plants, provided that the system does not leaks, algae and free from regardless of precipitation. Fig. 2a–e) show N, P, K, Ca and Mg consumption by tomato plants during the growing period. The nutrients consumption increase with increasing the flow rate. It indicate that when the flow rate increased from 4.0 to 6.0 L h⁻¹, the N, P, K, Ca and Mg consumption significantly increased from 0.005 to 0.041 (87.80%), 0.010 to 0.024 (58.33%), 0.073 to 0.280 (73.93%), 0.099 to 0.907 (89.08%) and 0.093 to 0.362 (74.31%) mg plant⁻¹, respectively, at the end of the growing period.

The results also indicate that the nutrients consumption increased gradually until it reached the peak after 75 day and then decreased. These results agreed with those obtained by Cooper (1979).

Multiple regression analysis was carried out to get a relationship between the nutrient consumption (NC, mg plant⁻¹), plant age (T, 1–120 day) and flow rate (Q, 4–6 L h⁻¹). The best form was as follows:

$$NC = a + bT + cQ \quad (1)$$

where:-

Table 1
The parameters used in the equations.

Parameter	Units	Value
a ₁	–	–0.335
a ₂	–	4.803
a ₃	–	755.3
a ₄	–	134.7
b ₁	–	0.946
b ₂	L m ⁻²	0.188
K	–	0.69
λ	MJ kg ⁻¹	2.45
GDD	–	1600

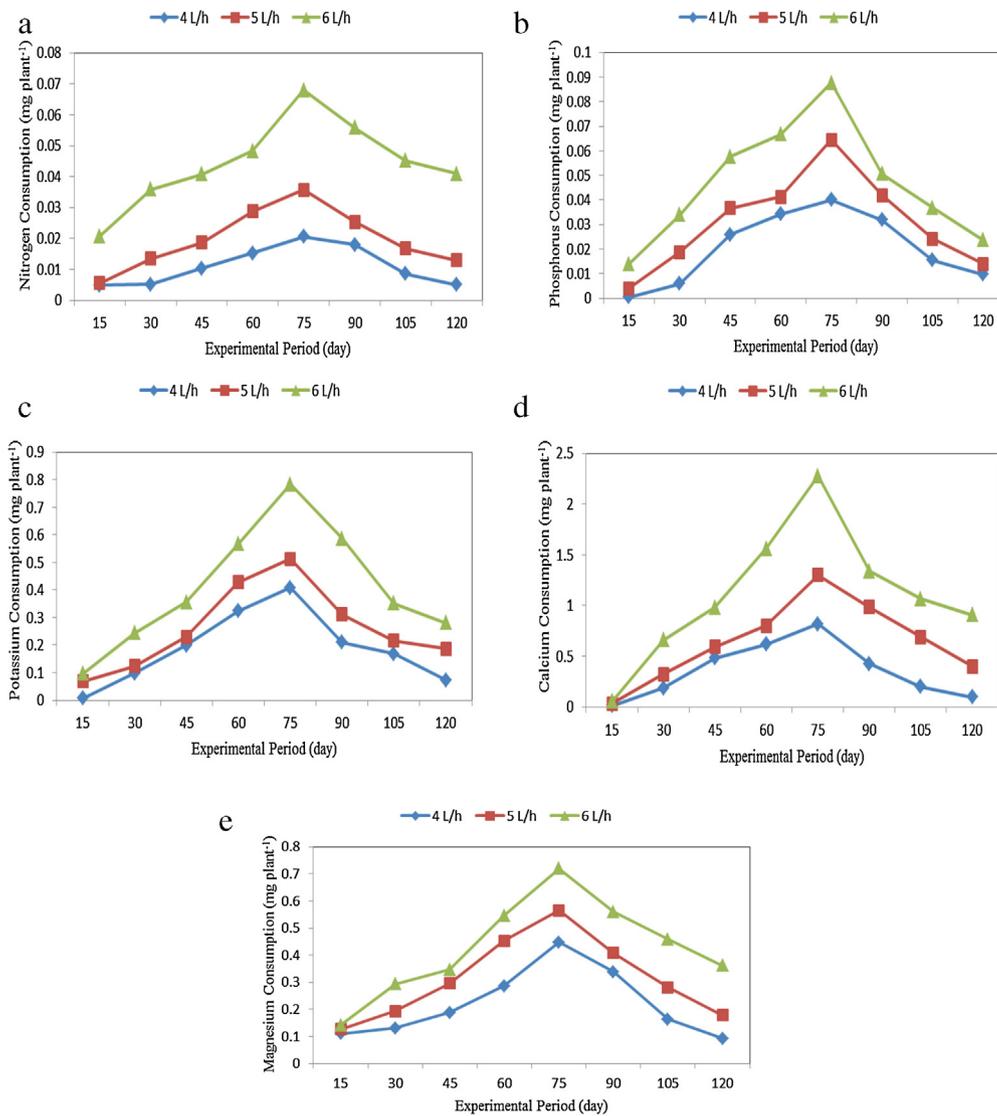


Fig. 2. (a) N consumption, (b) P consumption, (c) K consumption, (d) Ca consumption, (e) Mg consumption.

Table 2

The constants *a*, *b*, *c* and coefficient of determination for nutrients consumption at the different times and the different flow rates.

Items	<i>a</i>	<i>b</i>	<i>c</i>	<i>R</i> ²
N	−0.0657	0.0001	0.0168	0.943
P	−0.0375	0.0008	0.0129	0.796
K	−1.475	0.0044	0.3756	0.846
Ca	−0.3647	0.0014	0.1108	0.838
Mg	−0.2918	0.0013	0.1043	0.871

a, *b* and *c* are the constants

The constants of these equations and coefficient of determination are listed in Table 2.

3.2. Plant growth

3.2.1. Root length

Fig. 3 shows the root length of tomato plants grown by using the fish farm effluent at different flow rates (4–6 Lh^{−1}). It indicates that the root length increases with increasing flow rate and plant age. It could be seen that when the flow rate increased from 4.0 to 6.0 Lh^{−1}, the length of root significantly increased from 19.35 to 28.77

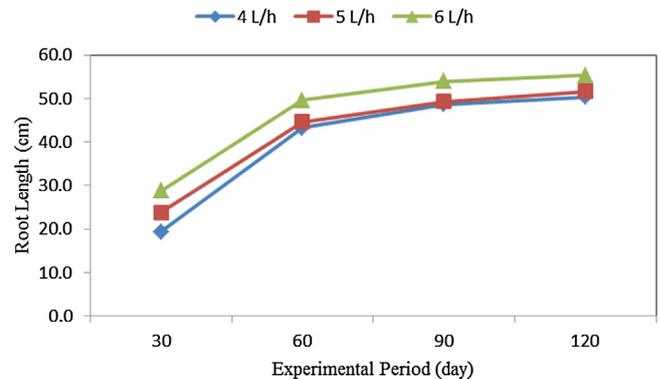


Fig. 3. The root length of tomato plants.

28.77 cm (32.74%) and 50.33 to 55.33 cm (9.04%) after 30 and 120 days, respectively, from transplanting. It also indicate that when the time after transplanting increased from 30 to 120 days, the length of root significantly increase from 19.35 to 50.33 and 28.77 to 55.33 cm at 4 and 6 Lh^{−1} flow rate, respectively.

The highest value of root length was 55.33 cm was obtained at a flow rate of 6.0Lh^{-1} , while, the lowest value of root length was 50.33 cm was obtained at a flow rate of 4.0Lh^{-1} . These results agreed with those obtained by Van Os (1983), Benoit (1987) and Fahim (1989).

Multiple regression analysis was carried out to get a relationship between the root length (RL, cm), plant age (T , 1–120 day) and flow rate (Q , 4– 6Lh^{-1}). The best form was as follows:

$$RL = 4.3938 + 0.3006T + 3.2613Q \quad R^2 = 0.944 \quad (2)$$

where:-

RL is the root length, cm

Statistical analysis shows that there were insignificant differences between the effect of both 4 and 5Lh^{-1} flow rates on the tomato root length, while there were significant different between the 6Lh^{-1} flow rate and the other flow rates (4 and 5Lh^{-1}) in their effect on the length. On the other hand, there were significant differences between the growth ages in their root length.

3.2.2. Shoot length

Fig. 4 shows the shoot growth of tomato plants that grown using the effluent fish farm with different flow rates. It indicates that the shoot length increases with increasing flow rate and plant age. It could be seen that when the flow rate increased from 4.0 to 6.0Lh^{-1} , the length of shoot significantly increased from 33.00 to 53.67 and 149.33 to 191.33 cm after 30 and 120 days, respectively, from transplanting. It also indicate that when the time after transplanting increased from 30 to 120 days, the length of shoot significantly increase from 33.00 to 149.33 and 53.67 to 191.33 cm at 4 and 6Lh^{-1} flow rate, respectively.

Increasing shoot length with increasing the length of root at 4.0 and 6.0Lh^{-1} effluent flow rates may be due to increasing in nutrient consumption rate, as indicated from the data of nutrient consumption. Tomato shoot length ranged from 149.33 to 191.33 cm depending treatments under study compared to 140.00–198.00 cm for the traditional cultivation (Lovelli et al., 2012).

Multiple regression analysis was carried out to get a relationship between the shoot length (SL, cm), plant age (T , 1–120 day) and flow rate (Q , 4– 6Lh^{-1}). The best form was as follows:

$$SL = -70.8168 + 1.4599T + 14.375Q \quad R^2 = 0.977 \quad (3)$$

Statistical analysis shows that there were significant differences between the treatments of flow rates on their effect on tomato shoot length. The same treatment was happened in the differences between the plant age effects on the shoot length.

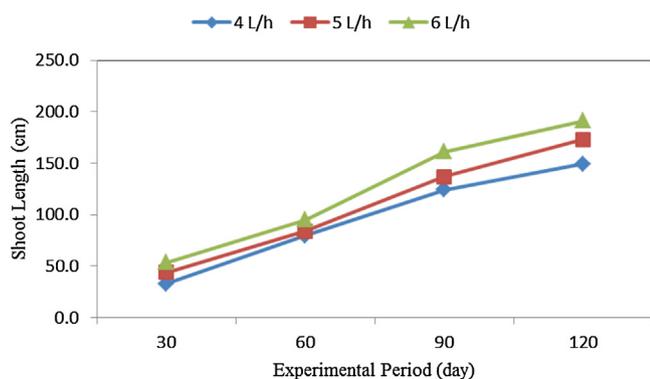


Fig. 4. The shoot length of tomato plants.

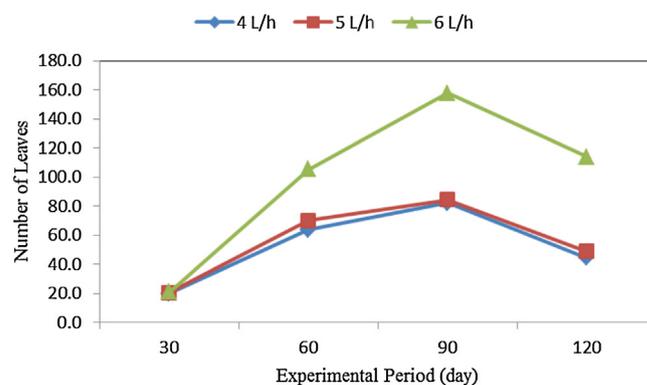


Fig. 5. The number of leaves of tomato plants.

3.2.3. Number of leaves:

Fig. 5 shows the number of leaves of tomato plants growing by the fish farm water disposed at different flow rates. It indicates that the number of leaves increases with increasing effluent flow rate and plant age. It could be seen that when the flow rate increased from 4.0 to 6.0Lh^{-1} , the number of leaves significantly increased from 20.00 to 21.00 (4.76%), 63.70 to 105.33 (39.52%), 82.33 to 157.67 (47.75%) and 44.33 to 114.00 (61.11%) after 30, 60, 90 and 120 days from transplanting, respectively.

The results also indicate that the number of leaves increased gradually until it reached the peak after 90 day and then decreased. The highest value of number of leaves was obtained after about 90 days from transplanting. The values of number of leaves were 82.33, 84.33 and 157.67 with 4.0, 5.0 and 6.0Lh^{-1} after 90 days from transplanting, respectively.

Multiple regression analysis was carried out to get a relationship between the number of leaves (NL), plant age (T , 1–120 day)

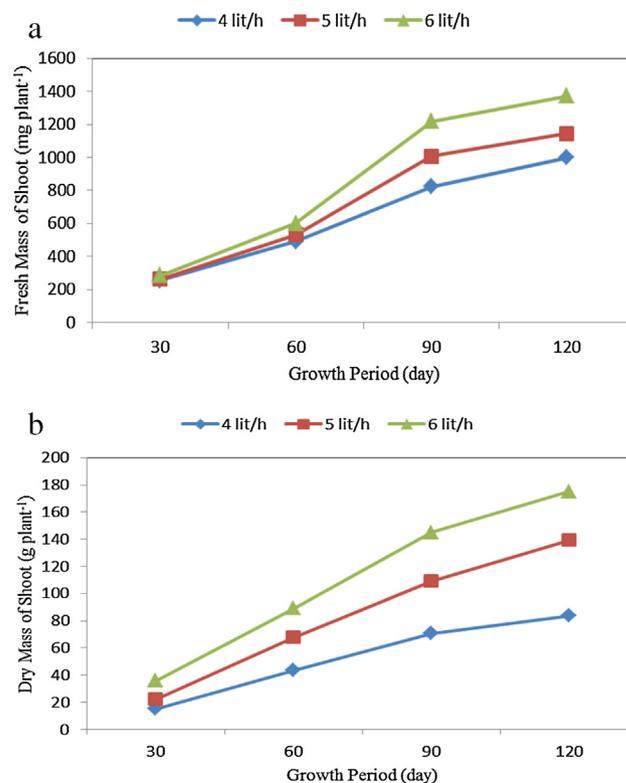


Fig. 6. (a) Fresh mass of shoot production of tomato plants during the growth period. (b) Dry mass of shoot production of tomato plants during the growth period.

and flow rate (Q , 4–6 L h⁻¹). The best form was as follows:

$$NL = -91.425 + 0.5802T + 23.455Q \quad R^2 = 0.832 \quad (4)$$

It is clear that using 6 L h⁻¹ had significant effect in the number of leaves of tomato compared to 4 and 5 L h⁻¹ which they had non-significant different between them which is might be due to increasing the nutrient consumption with the higher flow rate.

3.2.4. Fresh and dry mass of shoot

Fig. 6a and b shows the fresh and dry mass of tomato shoots that grown on effluent fish farms at different flow rates. The results indicate that the fresh and dry mass of shoot increase with increasing effluent flow rate. It could be seen that the fresh mass of shoot significantly increased from 253.99 to 998.10 (74.55%), 261.43 to 1145.15 (77.17%) and 284.59 to 1372.10 (79.26%) g plant⁻¹ at 4–6 flow rates, respectively. The Dry mass of shoot increased from 15.09 to 83.71 (81.97%), 22.25 to 139.32 (84.03%) and 35.71 to 175.09 (79.60%) g plant⁻¹ at 4–6 flow rates, respectively.

The highest value of fresh and dry mass of shoot were 1372.10 and 175.09 g plant⁻¹ was obtained at a flow rate of 6.0 L h⁻¹, while, the lowest value of fresh and dry mass of shoot were 998.01 and 83.71 g plant⁻¹ was obtained at a flow rate of 4.0 L h⁻¹. Fresh and dry mass of tomato shoot ranged from 998.01 to 1372.10 and 83.71 to 175.09 g plant⁻¹, respectively, depending treatments under study compared to 1270.60–1428.50 and 142.30–200.80 g plant⁻¹,

respectively for the traditional cultivation (Wahb-Allah et al., 2014).

There were significant differences between the plant fresh shoot mass due to the change of the different flow rates, plant age and interaction between flow rates and plant age. There were significant differences between dry mass of shoot during the different flow rates. There were significant differences between the plant dry shoot mass due to the change of the different flow rates. There were non-significant differences between shoot dry mass during the different plant ages and interaction between flow rates and plant age.

3.2.5. Fresh and dry mass of root

Fig. 7a and b shows the fresh and dry mass of tomato root that grown on effluent fish farms at different flow rates. The results indicate that the fresh and dry mass of root increase with increasing effluent flow rate. It could be seen that when the effluent flow rate increased from 4.0 to 6.0 L h⁻¹, the fresh mass of root increased from 115.23 to 388.07 (70.31%) and 137.01 to 423.91 (767.68%) g plant⁻¹, where, the Dry mass of shoot increased from 13.72 to 30.57 (55.12%) and 15.38 to 38.98 (60.54%) g plant⁻¹.

The highest value of fresh and dry mass of root were 423.91 and 38.98 g plant⁻¹ was obtained at a flow rate of 6.0 L h⁻¹, while, the lowest value of fresh and dry mass of root were 115.23 and 83.71 g plant⁻¹ was obtained at a flow rate of 4.0 L h⁻¹. Fresh and

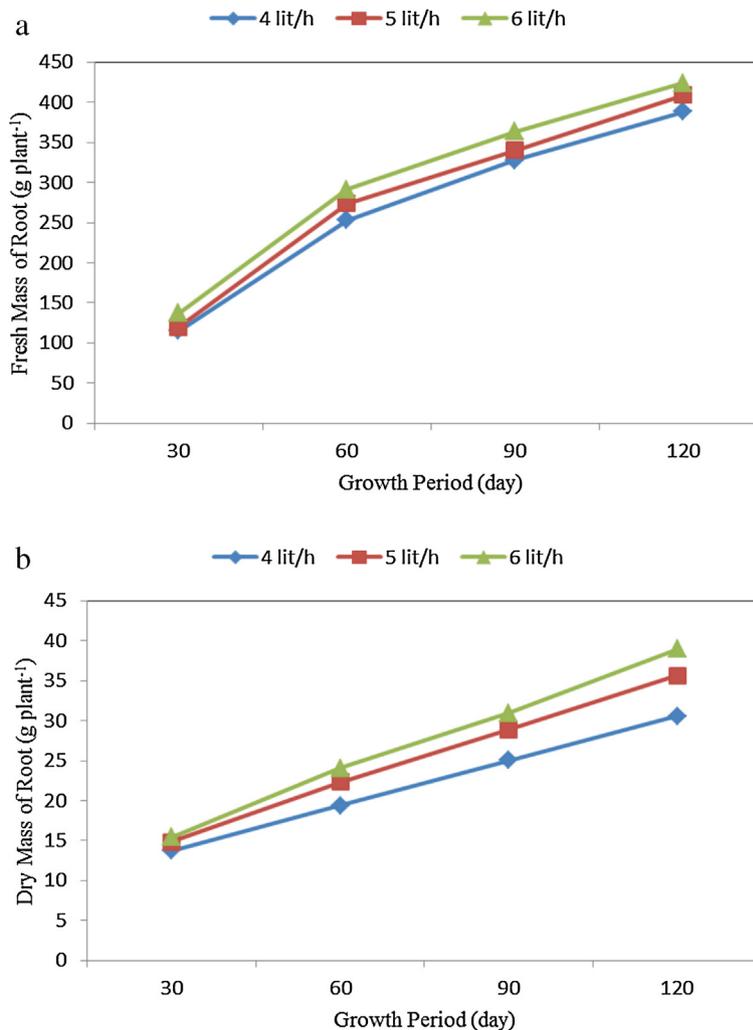


Fig. 7. (a) Fresh mass of root production of tomato plants at the end of growing period. (b) Dry mass of root production of tomato plants at the end of growing period.

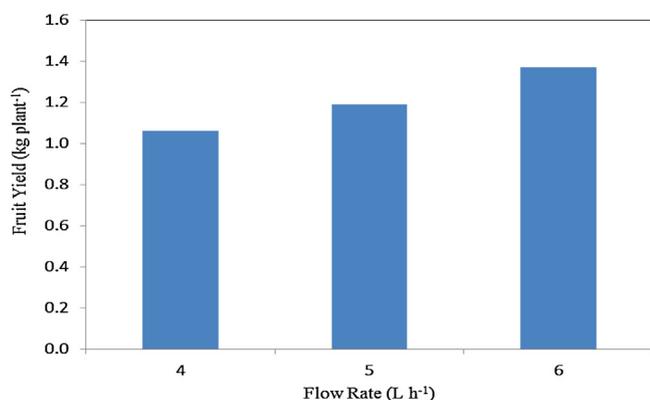


Fig. 8. Fruit yield of tomato plants at the end of growing period.

dry mass of tomato root ranged from 388.07 to 423.91 and 15.38 to 38.98 g plant⁻¹, respectively, depending treatments under study compared to 57.40–283.60 and 15.60–29.50 g plant⁻¹, respectively for the traditional cultivation (Wahb-Allah et al., 2014).

There were significant differences between the plant fresh root mass due to the change of the different flow rates and plant age. There were non-significant differences between root dry mass during the different flow rate and interaction between flow rates and plant age.

3.3. Tomato yield

3.3.1. Fruit yield

Fig. 8 shows the fruit yield of tomato plants grown on the effluent fish farms at different flow rates at the end of growing period. The results indicate that the fruit yield increases with increasing effluent flow rate. It indicates that when the flow rate increased from 4.0 to 6.0 L h⁻¹, the fruit yield significantly increased from 1.06 to 1.37 kg plant⁻¹ (22.63%).

The highest value of fruit yield (1.37 kg plant⁻¹) was obtained at a flow rate of 6.0 L h⁻¹, while, the lowest value of fruit yield (1.06 kg plant⁻¹) at a flow rate of 4.0 L h⁻¹. Tomato fruit yield ranged from 1.06 to 1.37 kg plant⁻¹ depending treatments under study compared to 1.351 to 1.771 kg plant⁻¹ for the traditional cultivation (Logendra et al., 2001).

Statistical analysis showed that there were significant differences between the fruit yield results due to the change of the different flow rates.

3.3.2. Fruit mass:

Fig. 9 shows the fruit mass of tomato plants grown on the effluent fish farms at different flow rates at the end of growing period. The results indicate that the fruit mass increases with

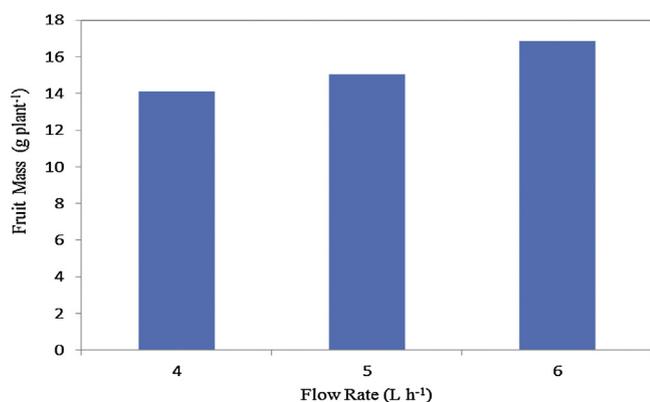


Fig. 9. Fruit mass of tomato plants at the end of growing period.

increasing effluent flow rate. It could be seen that when the flow rate increased from 4.0 to 6.0 L h⁻¹, the fruit mass increased from 75.07 to 81.32 g (7.69%).

The highest value of fruit mass (81.32 g) was obtained at a flow rate of 6.0 L h⁻¹, while, the lowest value of fruit mass (75.07 g) was obtained at a flow rate of 4.0 L h⁻¹. Increasing fruit mass was concomitant with increasing flow rates may be due to increasing in nutrient consumption rate, as indicated from the data of nutrient consumption. Tomato fruit mass ranged from 75.07 to 81.32 g depending treatments under study compared to 31.0–86.8 g for the traditional cultivation (Logendra et al., 2001).

Statistical analysis showed that there were non-significant differences between the fruit mass results due to the change of the different flow rates.

3.3.3. Number of fruits per plant

Fig. 10 shows the number of fruits per plant of tomato plants grown on the effluent fish farms at different flow rates at the end of growing period. The results indicate that the number of fruits increases with increasing effluent flow rate. It indicates that when the effluent flow rate increased from 4.0 to 6.0 L h⁻¹, the number of fruits increased from 14.12 to 16.85 (16.02%).

The highest value of number of fruits (16.85) was obtained at a flow rate of 6.0 L h⁻¹, while, the lowest value of number of fruits (14.12) was obtained at a flow rate of 4.0 L h⁻¹. Increasing number of fruits was concomitant with increasing the length of shoot at 4.0 and 6.0 L h⁻¹ flow rates may be due to increasing in numbers of node. Number of fruits ranged from 14.12 to 16.85 depending treatments under study compared to 12.80–24.3 for the traditional cultivation (Anderson, 1997).

Statistical analysis showed that there were significant differences between the numbers of fruit results due to the change of the different flow rates.

3.4. Water use efficiency

Fig. 11 shows the water use efficiency of tomato plants grown using the effluent fish farms with different flow rate at the end of growing period. The results indicate that the water use efficiency increases with increasing effluent flow rate. It indicates that when the effluent flow rate increased from 4.0 to 6.0 L h⁻¹, the water use efficiency increased from 5.54 to 7.16 kg m⁻³ (22.63%).

The highest value of water use efficiency was 7.16 kg m⁻³ was obtained at a flow rate of 6.0 L h⁻¹, while, the lowest value of water use efficiency was 5.54 kg m⁻³ was obtained at a flow rate of 4.0 L h⁻¹. Water use efficiency by tomato plant ranged from 5.54 to 7.16 kg m⁻³ depending treatments under study compared to 15.5–16.8 kg m⁻³ for the traditional cultivation (Wahb-Allah et al., 2014).

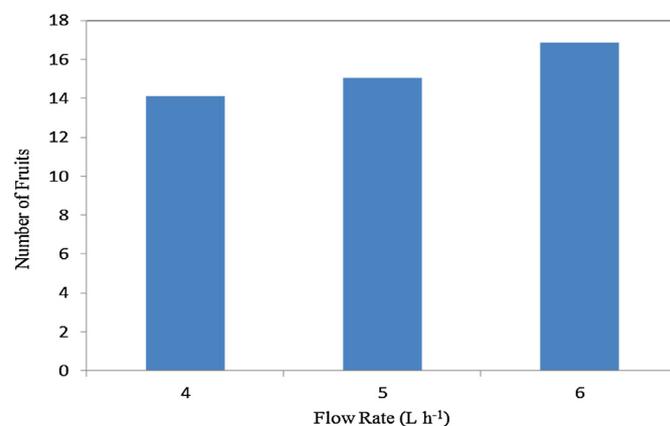


Fig. 10. The number of fruits per plant of tomato plants at the end of growing period.

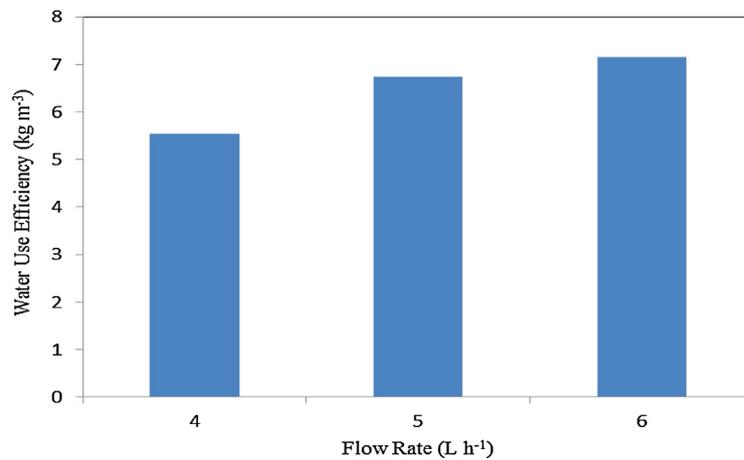


Fig. 11. The water use efficiency of tomato plants at the end of growing period.

Table 3

The total operation costs of tomato production in hydroponics and aquaponics systems.

Cost Item	Units	Production system	
		Hydroponics	Aquaponics
Fixed cost (LE)			
Greenhouse	LE kg ⁻¹	0.40	0.40
Culture units	LE kg ⁻¹	0.10	0.10
Pumps and fittings	LE kg ⁻¹	0.09	0.09
Total fixed cost	LE kg ⁻¹	0.59	0.59
Variable cost (L.E)			
Tomato seeds	LE kg ⁻¹	0.08	0.08
Cups	LE kg ⁻¹	0.05	0.05
Peat moss	LE kg ⁻¹	0.06	0.06
Labor	LE kg ⁻¹	0.30	0.30
Energy	LE kg ⁻¹	0.25	0.25
Fertilizers	LE kg ⁻¹	0.12	–
Chemicals	LE kg ⁻¹	0.11	0.11
Plant support	LE kg ⁻¹	0.06	0.06
Total variable cost	LE kg ⁻¹	1.04	0.91
Total direct cost	LE kg ⁻¹	1.62	1.50
Indirect Wages	LE kg ⁻¹	0.15	0.15
Deprecation	LE kg ⁻¹	0.16	0.15
Maintenance	LE kg ⁻¹	0.10	0.10
Total indirect cost	LE kg ⁻¹	0.41	0.40
Total Cost	LE kg ⁻¹	2.03	1.90

0.073 to 0.280 (73.93%), 0.099 to 0.907 (89.08%) and 0.093 to 0.362 (74.31%) mg plant⁻¹, respectively, with increasing flow rate from 4.0 to 6.0 L h⁻¹.

- The root length increases with increasing flow rate, when the flow rate increased from 4.0 to 6.0 L h⁻¹, the length of root significantly increased from 50.33 to 55.33 cm (9.04%) at the end of growing period.
- The shoot length increases with increasing flow rate and time, when the flow rate increased from 4.0 to 6.0 L h⁻¹, the length of shoot significantly increased from 149.33 to 191.33 cm at the end of growing period.
- The fresh and dry mass of shoot significantly increased from 998.01 to 1372.10 and 83.71 to 275.09 g plant⁻¹, respectively, with increasing flow rate from 4.0 to 6.0 L h⁻¹. The fresh and dry mass of root significantly increased from 388.07 to 423.91 and 30.37 to 38.98 g plant⁻¹, respectively, with increasing flow rate from 4.0 to 6.0 L h⁻¹.
- The fruit yield significantly increased from 1.06 to 1.37 kg plant⁻¹ with increasing flow rate from 4.0 to 6.0 L h⁻¹. The fruit mass and number of fruits increased from 75.07 to 81.32 g and 14.12 to 16.85 with increasing flow rate from 4.0 to 6.0 L h⁻¹, respectively.
- The water use efficiency increased from 5.54 to 7.16 kg m⁻³ with increasing flow rate from 4.0 to 6.0 L h⁻¹. Using the effluent fish farm could save fertilizers which equivalents 0.13 LE kg⁻¹ fruits (130 LE t⁻¹ fruits). Besides it is considered as an organic product which is safe for the human health. Further work should be carried out to study the effect of more parameters such the environmental parameters on the water use efficiency, plant growth and yield.

3.5. Feasibility of utilizing the effluent fish farm in tomato cultivation

Table 3 shows the total operation costs of tomato production in hydroponics and aquaponics systems. It could be seen that using the effluent fish farm could save fertilizers which equivalents 0.13 LE kg⁻¹ fruits (130 LE t⁻¹ fruits). Besides it is considered as an organic product which is safe for the human health.

4. Conclusions

The experiment was carried out to study to which extent the content of nutrients in water farming is sufficient for growing tomato plants, in order to increase the yield and reduce the production costs. The obtained results can be summarized as follows:

- The nutrients consumption were increased with increasing the flow rate. The N, P, K, Ca and Mg consumption significantly increased from 0.005 to 0.041 (87.80%), 0.010 to 0.024 (58.33%),

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