

USING OF AGRICULTURAL DRAINAGE WATER FOR LETTUCE PRODUCTION IN HYDROPONIC SYSTEM

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ABSTRACT

*The objectives of the present work were to study the effects of irrigation with Agricultural Drainage Water (ADW) on lettuce (*Lactuca sativa* L.) yield, quality, and water use efficiency (WUE) with hydroponic system. Five mixing treatments of Agricultural drainage water (ADW) with fresh water (mean normal irrigation water) were used T1:(100% agricultural drainage water), T2:(75% agricultural drainage water mixed with 25% fresh water), T3:(50% agricultural drainage water mixed with 50% fresh water), T4:(25% agricultural drainage water mixed with 75% fresh water), and T5:(100% fresh water). Nutrient Film Technique (NFT) hydroponic system was developed with five pipes PVC and nutrient solution added in rates: 12.5%, 25%, 50%, 75%, and 100% from standard nutrient solution for T1, T2, T3, T4, and T5, respectively. The results showed that lettuce plant can be produced in 50 days from planting to harvest by (NFT) hydroponic system. Moreover irrigation by using T3 had effectively increased the yields of green and dry matter. The higher Lettuce yields obtained with trend $T3 > T5 > T2 > T4 > T1$. And plants irrigated with T3 used water more efficiently than those irrigated with other water treatments. The higher water use efficiency (WUE) 39.96 kg/m³ was obtained with T3 and the lower value 16.67 with T1. On the other hand mineral nutrient contents in dry matter of N, P, K, and Ca contents were obviously higher in plants irrigated with T5 than with other water treatments. Heavy metals (Cd, Ni, Cr and Pb) contents in Lettuce shoots were higher in plants irrigated with T3 than those irrigated with other water treatments, but their levels did not reached the maximum allowed levels by FAO for edible crops.*

Keywords: *Agricultural Drainage Water, Hydroponic system, Lettuce, Water use efficiency.*

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INTRODUCTION

Now it is very important to use alternative water resources such as agricultural drainage water to produce crops. Growing lettuce hydroponically is now becoming popular in drought prone areas to produce lettuce plants in large quantities with less water use. Egypt is an arid country, which covers an area of about 1,001,450 km² of which only 4% is occupied by its population. The population has tripled during the last 50 years from 19 million in 1947 to about 83.5 million in 2012 and expected to be about 100 million by the year 2025 (**Abdel-Lateef et. al., 2011**). About 99% of the Egyptian population is concentrated within 5.5% of the area of the Nile Valley and Delta region. They are extremely dependent on the River Nile for agriculture, drinking water and energy. Where, the actual water resources currently available for use in Egypt are 55.5 Bm³/yr from river Nile, and 1.3 Bm³/yr effective rainfalls on the northern strip of the Delta, non-renewable groundwater for western desert and Sinai, while water requirements for different sectors are in the order of 79.5 Bm³/yr. The gap between the needs and availability of water is about 20 Bm³/yr. This gap is overcome by recycling. Moreover, hydroponics (soilless) culture could lead to solve the global issues such as the shortage of water, environmental pollution, and instability of ecological system in various ways. Constituting high values for agricultural crops by using low water inputs and high fertilizer efficiencies is one of the methods used in addressing the environmental and resource problems (**Sezen et. al., 2010**).

On the other hand the agricultural sector is utilizing about 86% of the available water supplies; however, this amount of water that returns to drains from irrigated lands is relatively high (about 25 to 30%). Generally, the drainage water from agriculture is collected, by an extensive drainage network. Currently about 5.5 Bm³ of drainage water are being reused after mixing with fresh water. This amount is expected to increase up to 9.6 Bm³ by the year 2017. In general, the utilization of agricultural drainage water (ADW) and marginal quality surface water is an emerging necessity to deal with severe water shortage in arid and semi-arid land. Upgrading of ADW may enable appropriate schemes for controlled application depending on treated ADW or via mixing with other sources of surface water. Its reuse in Egypt for agriculture could

bridge the gap between the expected (74 milliard m³) and required (85 milliard m³) water demand. In addition, Agriculture drainage water can be considered as a nutrient-rich resource that can be used for food production and thus help alleviate food shortages with minimum use of chemical fertilizers. However, whatever its application, and whatever the type and level of treatment technologies, they must meet the recommended microbiological and chemical quality guidelines. These presume low cost and minimal operational and maintenance requirements. Hydroponics is a method of growing plants in a soil-less media. The nutrient source is provided directly to the plant roots in solution. Recent studies have indicated that nutrients from treated ADW could be purified by using some plant species in a hydroponic system (**Vaillant et al., 2004; Yang et al., 2008; Snow and Ghaly, 2008; Rababah and Ashbolt, 2000; Rababah and al-Shuha, 2009**). Hydroponic culture could be arranged with optimum environmental medium for crop growth in order to gain maximum yield and high quality products. However, there are few studies on the nutrient availability in Agriculture drainage water for optimum plant growth, pathogen contamination in edible parts of the plant and nutritional quality of vegetables grown in Agriculture drainage water using the hydroponics system. One of the most important aspects of fresh food is its nutritional quality; however, it is not clear whether Agriculture drainage water is able to provide necessary nutrients to food crops as well as adequate nutritional quality of the produce. **Brandley and Marulanda (2000)** reported that hydroponic vegetables production technique requires only about 10-20% of the water needed to produce the same amount of crop in soil culture. While **Al-Karaki (2010)** reported that only 3-5% of water is needed to produce the same amount of plants in comparison to that produced under field conditions. **Gonnella M., et al., (2003)** found that Water consumption was near to 80 L/m² when lettuce grown in floating system regardless of plant density, while WUE resulted on average 3.5 g of leaf dry matter produced per liter of water consumed. The benefits of hydroponic agriculture are numerous. In addition to higher yields and water efficiency, when practiced in a controlled environment, hydroponic systems can be designed to support continuous production throughout the year (**Brechner and Both, 2014**). Hydroponic

systems are very versatile and can range from rudimentary backyard setups to highly sophisticated commercial enterprises. Various commercial and specialty crops can be grown using hydroponics including tomatoes, cucumbers, peppers, eggplants, strawberries, and many more. Leafy vegetables, such as lettuce can also be grown hydroponically and perform best using the nutrient film technique (NFT) (**Tognoni and Pardossi, 2015**). Hydroponic NFT production involves the circulation of a nutrient solution through shallow channels in a closed-loop system (**Albright and Langhans, 2014**). Hydroponic systems are optimal efficiency in the use of water and nutrients, with high environmental benefit (**Vernieri et al., 2005**). The current study aimed to investigate Lettuce yield, water use efficiency, and quality and heavy metal contents of the hydroponically produced Lettuce using agricultural drainage water (ADW) for irrigation and compare it with fresh water irrigation.

MATERIALS AND METHODS

The experimental work was carried out during 2013 at the Department of Soil and Water Research, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. It's located at 30° 24` N latitude, 31° 35` E longitude while the altitude is 20 m above the sea level. The Nutrient Film Technique (NFT) culture was developed and manufactured at a local workshop used in this work.

Lettuce (*Lactuca sativa* L.) seeds were sowing on 1 September. 2013 in Rockwool and transplanted 3 week later into rock wool blocks. On 21 September 2013, at the four- to five-leaf stage, transplants were placed in net cups and were inserted in the NFT hydroponic systems. The NFT systems were made of plastic PVC Pipes (300 cm long × 4 inch (10.16 cm) diameter) set on a flat surface with a 0.1% slope. Each experimental bloc had twelve plants; each effluent was complemented with appropriated nutrient solution. Block with five treatments and three repetitions of each treatment were applied showed in Figure 1. After seeding, lettuces were transferred to the experimental units. Irrigation was added by a little submersible pump (Mp-1500, power 40W, 50-60 Hz) was used to pump from the circulating tank to the head of the NFT channels where the plants were grown bare-rooted. The irrigation of plants was programmed with a

timer to put on the pumps 4 times every day for 5 minutes per time and nutrient solution was delivered at $2 \text{ L}\cdot\text{min}^{-1}$. Nutrient solutions were monitored and adjusted daily for pH and electrical conductivity (EC). In the NFT system the solution was recycled not replaced but adjusted based on pH and EC measurements.

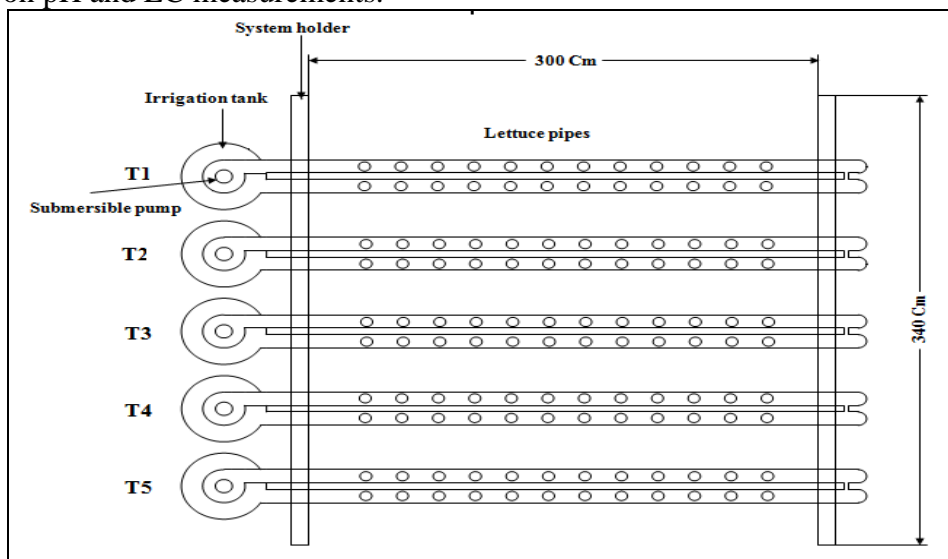


Figure 1: Schematic layout of the hydroponic system used in the study

The seeds were obtained from Agricultural Research Centre, Dokki, Cairo, Egypt. Lettuce (*Lactuca sativa L.*) seeds were subjected to a germination test to check for their viability before being used; the results showed that the germination percentage was 97%. Seeds of lettuce were cleaned from debris and other foreign materials. Then the cleaned seeds were surface sterilized by soaking for 30 minutes in a 20% sodium hypochlorite solution (Clorox bleach) to prevent the formation of mould. Planting tubes and the growing net cups also were cleaned and disinfected. The seeds were washed well from residues of bleach and re-soaked in tap water overnight (about 12 hours) before sowing. Seeds were sown in the polystyrene trays lined with black plastic sheets and have holes at the bottom to allow drainage of excess water from irrigation.

Irrigation treatments

Pipes were irrigated by programming a timer to put on the pumps four times every day for five minutes per time with five water treatments: Five

concentrations of Agricultural drainage water (ADW) were used T1: (100% agricultural drainage water), T2: (75% agricultural drainage water mixed with 25% fresh water (normal irrigation water), T3: (50% agricultural drainage water mixed with 50% fresh water), T4: (25% agricultural drainage water mixed with 75% fresh water), and T5: (100% fresh water). The Agricultural drainage water (ADW) was obtained from the outlet of drainage system of Minayer Region with a capacity of 2,500 m³/day. Adequate nutrient solutions was added in each treatment with rates of 12.5%, 25%, 50%, 75%, and 100% from standard nutrient solution for T1, T2, T3, T4, and T5 respectively to enhance plant growth and its contents of the nutritional elements. The irrigation system was installed in hydroponics system as follows: the different concentration of mixed agricultural drainage water was pumped from a 50L reservoir to the channel where plants were grown. The 4 inch diameter x 3 m length channels were connected by an inlet and outlet to the reservoir. The volume of solution in one channel at any one time was approximately 5L. The effluent was drained by gravity flow back into the reservoir.

Water use efficiency

Planting pipes were irrigated four times every day for five minutes from each water type to provide enough water to keep the seedlings moist. Daily amounts of water used in irrigation were recorded to compute the total amounts used in irrigation throughout the experiment. Drained water was recycled in the plastic tanks which were placed under each planting pipe. The total water used by plants (liters/pipe) was computed as the following:

Water consumption (m³/m²) = Total irrigation water in tank at the beginning of the experiment - Total irrigation water in tank at the end of the experiment.

Water use efficiency (WUE) was determined according to **Awady et al. (1976) and Bos (1980)** using the following equation:

$$WUE = \frac{\text{Average yield } kg / fed}{\text{Amount of applied water } m^3 / fed} \quad kg / m^3$$

WUE= kg fresh lettuce produced / m³ water used.

Lettuce yield

At the end of experiment (50 days after seeding), the produced fresh lettuce was harvested and green plants with their root mats in the tubes were harvested and the following data were recorded: total fresh and dry lettuce yields, plant height, and leaves number.

Chemical analysis**Mineral nutrient analyses**

Representative fresh green lettuce samples (150 g) from each treatment were taken in four replicates at harvest, oven-dried at 70°C for 48 hours, ground to pass a 0.5 mm sieve, and digested used H₂SO₄ and H₂O₂ and then used for chemical analysis. The nitrogen content was determined using Kjeldahl's method. Samples for the determination of mineral nutrients were prepared using dry ashing method (**Schouwenberg and Walinge, 1973**). Phosphorus was determined using spectrophotometer (**Watanabe and Olsen 1965**); potassium and sodium by flame photometer (**Ryan et al., 2001**), Ca, Mg, Mn, Zn and B by Atomic Absorption Spectrometer (Buck type 210). Some nutritional elements (N, P, K, Ca, Mg, Zn, Na, and B) for various irrigation waters were also analyzed.

Heavy metals analysis

Heavy metals analyses were carried out at the Department of Soil and Water Research, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. Dried and ground plant samples were analyzed for heavy metals Cd, Ni, Cr, and Pb were measured in the 0.2 portion dry ash digestion for the lettuce dried samples. Chemical analyses for various irrigation waters were also carried out separately for heavy metals (Cd, Ni, Cr and Pb).

RESULTS AND DISCUSSION**Irrigation water quality**

The analysis of irrigation water used for the various treatments was showed in Table 1. The salinity of water was 0.89 dS/m for fresh water and 2.63 dS/m for Agricultural drainage water (ADW). The pH values were 7.42 for the fresh water and 7.95 for the ADW. Nitrogen, K, Na, Cl and Zn were present in higher concentrations in ADW compared to fresh water (Table 1). However, similar amounts of P, Mg, and B were

recorded in both ADW and fresh water. The concentrations of these elements are considered lower than those recommended for nutrient solutions in crop production (e.g., vegetables) under hydroponic systems according to **Benton (2005)**.

To know the potential risk of heavy metals in irrigation water to plants and hence human beings, it is necessary to evaluate their concentrations in ADW. The heavy metals concentrations of ADW and fresh water used in this study was presented in Table 2. Although the chromium, cadmium, nickel, and lead contents in ADW are much higher than those in fresh water, the levels of these elements in ADW are lower than the acceptable levels set for irrigation water for crop production according to FAO guidelines (**FAO, 1992**).

Table 1. The characteristics of fresh water and ADW used for irrigation in this study

Parameter	Fresh water (Normal irrigation water)	Agricultural drainage water (ADW)
EC dS/m	0.89	2.63
pH	7.42	7.95
DO (mg/l)	-	2.8
BOD ₅ (mg/l)	-	40
COD (mg/l)	-	38
NO ₃ -N (mg/l)	14	23
Cl (mg/l)	17	129
PO ₄ -P (mg/l)	4.96	6.58
Ca (mg/l)	48.12	59.32
Mg (mg/l)	15.9	17.3
K (mg/l)	98	118
Na (mg/l)	78.4	389
Zn (mg/l)	0.016	0.15
B (mg/l)	0.038	0.050

Table 2. Toxic elements content (mg.L^{-1}) in water used for irrigation and the maximum concentrations of heavy metals in ADW allowed to be used for irrigation according to **FAO (1992)**.

Heavy Metal	ADW	Fresh water (Normal irrigation water)	Maximum concentrations
Chromium (Cr)	0.0070	0.0018	0.10
Cadmium (Cd)	0.0023	0.0004	0.01
Nickel (Ni)	0.0082	0.0004	0.20
Lead (Pb)	0.167	0.0029	5.00

Lettuce yield

Lettuce fresh weight (shoots and roots) as affected by different water quality was presented in Table (3), and graphically illustrated by Fig. (2). It is obvious that treatment of 50% drainage water mixed with 50% fresh water (T3) induced the highest value of shoots and roots fresh weight followed by treatment (T5), then the treatment (T2). On the other hand, the treatment of 100% drainage water (T1) resulted in the lowest value of shoots and roots fresh weight followed by T4.

The results presented in Table 3 showed that higher yields of fresh and dry matter were recorded in plants irrigated with T3 more than for others. Table 3 and Figures 2, 3 showed that lettuce yields (on fresh green and dry weight basis), plant heights and leaves number at harvest. Average fresh Lettuce yield obtained were 4.00, 7.42, 9.99, 7.25, and 7.77 kg/m^2 under irrigation with T1, T2, T3, T4, and T5, respectively. It could be concluded that, the application of irrigation with T3 resulted in high increase in fresh green yield production of lettuce plant, in addition the yield production under application of different water treatment could be ranked in the following descending order: T3>T5>T2>T4>T1. Similar trends were observed with dry yield, where Average dry Lettuce yield obtained were 0.20, 0.37, 0.49, 0.36, and 0.39 kg/m^2 under irrigation with T1, T2, T3, T4 and T5, respectively. Where the high dry yield production was obtained with T3 followed by T5, T2 and T4, then the lowest dry yield production was obtained with T1 similar results found by **Gonnella M. et al., (2003)** and **Keller R. et al., (2005)**. These results also agreed with those obtained by **Khater (2006)** and **Genuncio et al., (2012)** who's found that the

highest values of fresh and dry mass were found with a flow rate of $1.5 \text{ Lh}^{-1}\text{plant}^{-1}$. Plant dry matter was reduced with increasing salinity and this is consistent with **Al-Maskri A. et al., (2010)**. Regarding to plant height, Average Lettuce height obtained were 44.34, 58.58, 62.16, 58.33 and 60.75 cm under irrigation with T1, T2, T3, T4 and T5, respectively. the highest plant were obtained with T3 that's may be due to salinity level provide more nutrients availability when compared with other treatments this results agreement with **Al-Maskri A. et al., (2010)**.

Table3. Lettuce (fresh, dry) yield, plant height, and leaves numbers of lettuce plant produced under (NFT) hydroponic conditions and irrigated with different concentrations of Agricultural Drainage Water (ADW).

Water treatments	Fresh yield kg/m ²	Dry yield kg/m ²	plant height, cm	leaves number
T1	4.00	0.20	44.32	17
T2	7.42	0.37	58.58	20
T3	9.99	0.49	62.16	25
T4	7.25	0.36	58.33	27
T5	7.77	0.39	60.75	30

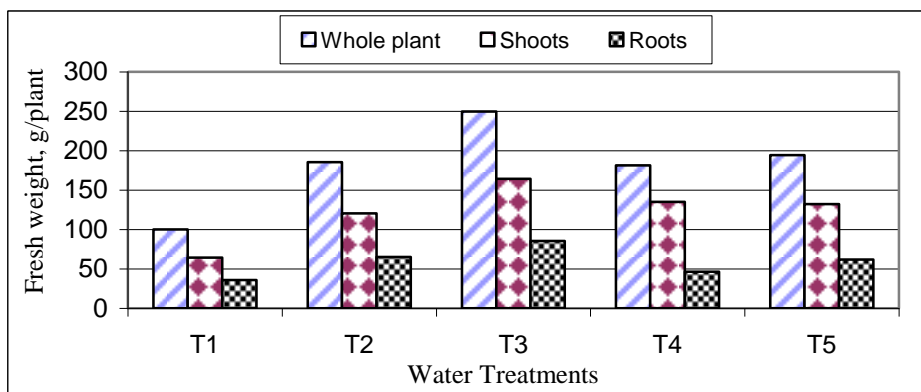


Figure 2: Effect of irrigation water treatments on fresh weight ($\text{g}\cdot\text{plant}^{-1}$) of Lettuce plant.

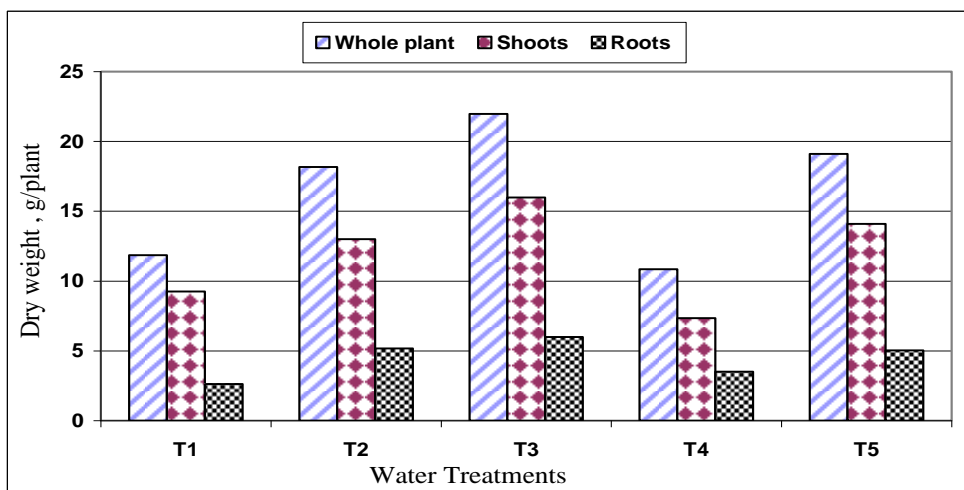


Figure 3: Effect of irrigation water treatments on dry weight ($\text{g}\cdot\text{plant}^{-1}$) of Lettuce plant

Lettuce plant height

Lettuce plant height (shoots and roots) as affected by different water quality is presented in Table (3), and graphically illustrated by Fig. (4). It is obvious that treatment T4 induced the highest value of shoot height followed by treatment (T3), then the treatment (T5). On the other hand, the treatment of 100% drainage water (T1) resulted in the lowest value of shoot height followed by T2. On the base of fully drainage water treatment, other water quality treatments reflected relative increase in shoot height by about 3%, 29%, 50% and 18% over T1 for T2, T3, T4 and T5, respectively.

On the other hand, results of root height showed that treatment of 75% drainage water mixed with 25% fresh water (T2) induced the highest value of root height followed by (T5), then the treatment (T3). On the other hand, the treatment (T1) resulted in the lowest value of root height followed by T4.

In general, the highest plant were obtained with T3 that's may be due to salinity level provide more nutrients availability when compared with other treatments this results agreement with **Al-Maskri, A., et al. (2010)**.

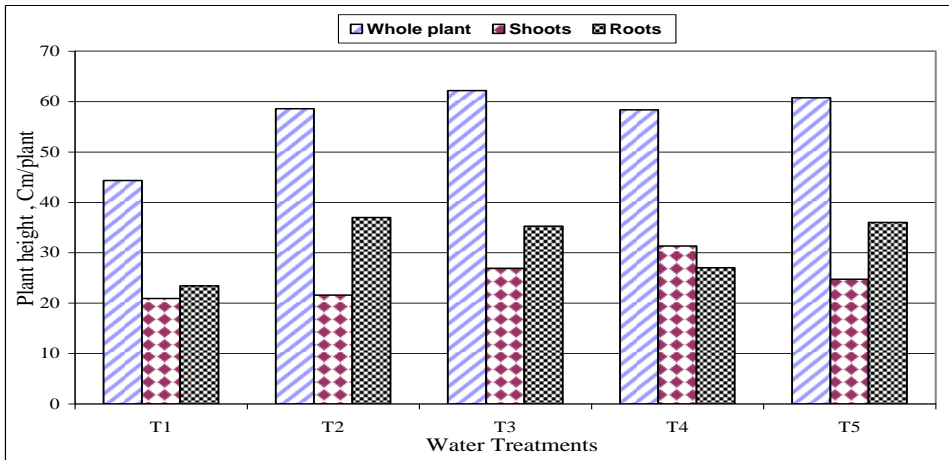


Figure 4: Effect of irrigation water treatments on plant height (cm.plant⁻¹) of Lettuce plant

Lettuce leaves number

Lettuce leaves number as affected by different water quality is presented in Table (3), and graphically illustrated by Fig. (5). It is obvious that treatment of 100% fresh water (T5) induced the highest value of leaves number followed by treatment of 25% drainage water mixed with 75% fresh water (T4), then the treatment of 50% drainage water mixed with 50% fresh water (T3).

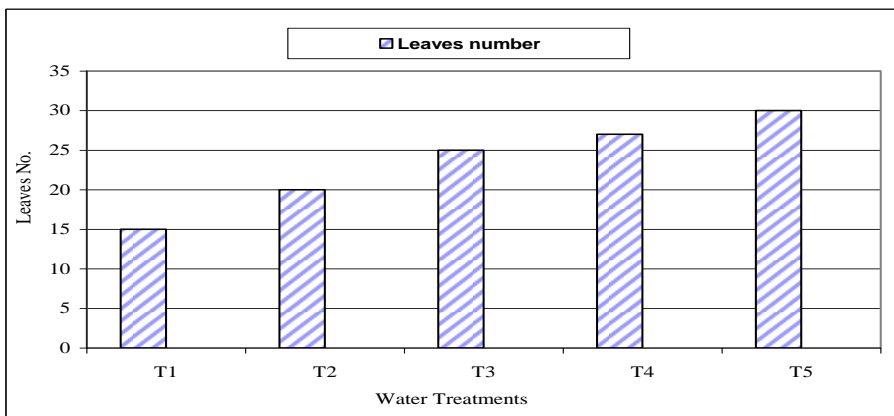


Figure 5: Effect of irrigation water treatments on Leaves Number of Lettuce plants

On the other hand, the treatment of 100% drainage water (T1) resulted in the lowest value of leaves number followed by T2 (75% drainage water

mixed with 25% fresh water). On the base of fully drainage water treatment, other water quality treatments reflected simple relative increase in leaves number by about 17.5%, 47%, 59% and 76% over T1 for T2, T3, T4 and T5, respectively similar results was reported by **Ünlükara et al. (2008)**.

Water use efficiency

Hydroponically produced lettuce was found to enhance the efficiency of water use (WUE). **Bradley and Marulanda (2000)** reported that hydroponic green fodder production technique requires only about 10-20% of the water needed to produce the same amount of crop in soil culture. While **Al-Karaki (2010)** reported that only 3-5% of water is needed to produce the same amount of fodder in comparison to that produced under field conditions. Producing Lettuce under hydroponic conditions is a highly efficient process in term of water saving when compared to field production of different plants like lettuce. In this study, the results in table 4 and fig. 6 showed that the highest value of (WUE) was obtained with T3 and the lowest value obtained with T1 as the high fresh yield with T3 and low fresh yield with T1. Irrigation with T3 was found to use water more efficiently in producing Lettuce plant than irrigation with the other water treatments, when used only 1m³ water to produce 16.67kg of hydroponic lettuce in comparison to 29.68, 39.96, 27.88 and 28.78 kg of produced lettuce in T1, T2, T3, T4, and T5, respectively.

Table 4: Total water consumption during lettuce cultural cycle and water use efficiency

Water treatments	Total water consumption	Fresh matter kg/m ²	Water use m ³ /kg fresh matter	Water use efficiency kg fresh matter/ m ³
	m ³ /m ²			
T1	0.24	4.00	0.060	16.67
T2	0.25	7.42	0.034	29.68
T3	0.25	9.99	0.025	39.96
T4	0.26	7.25	0.036	27.88
T5	0.27	7.77	0.035	28.78

Generally, most hydroponic systems will utilize water more efficiently than conventional farming. The volume of water consumed per plant in a hydroponic system is not different from that grown using conventional methods; however, the hydroponic system delivers the water more efficiently, with a larger percentage of the water going to plant evapotranspiration (Sanchez 2014).

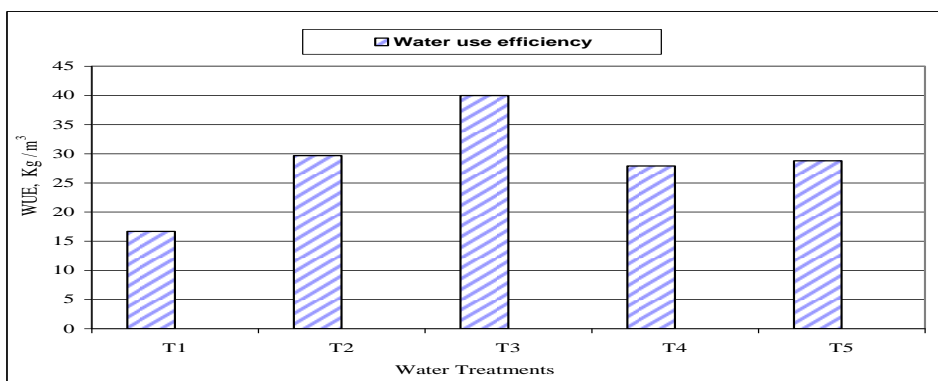


Figure 6: Water use efficiency (kg/m^3) for lettuce plant during cultural cycle

This is a tremendous improvement in WUE and indicated that hydroponic system could play a significant role in improving water use efficiency in Egypt and other countries in the region with shortage in irrigation water.

Lettuce quality

Nutrient minerals contents in Lettuce

Minerals have a major nutritional significance for human beings and feed deficiencies in elements, such as N, P, K, Ca, Cu, Fe, Zn and Mn can lead to a variety of health problems (Liu et al., 2007). Concentration of nutrient elements analyzed in dry Lettuce is presented in Table 5. There were obvious differences in concentrations of the analyzed elements (N, P, K, Ca, Cu, Fe, Zn and Mn) between those irrigated with ADW and with fresh water or ADW mix. The short growing period of Lettuce under hydroponic dependency on its own reserved compounds for the early growing stages may be attributed to the high variations of mineral nutrients in the produced Lettuce irrigated with ADW and fresh water.

The nutrient requirements of the seedlings after germination are quite low and partially satisfied from the reserved compounds in the seeds (**Bewley, 1997**).

Table 5. The uptake of mineral nutrients in Lettuce plant produced under hydroponic conditions and irrigated with different water treatments (dry matter basis).

Water treatment	N	P	K	Ca	Cu	Fe	Zn	Mn
	mg plant ⁻¹				µg plant ⁻¹			
T1	94.25	11.25	144.64	30.56	0.27	24.99	1.457	1.278
T2	156.26	16.18	241.72	42.43	0.47	31.63	1.708	1.618
T3	281.42	31.91	507.99	80.77	0.87	56.223	3.338	2.097
T4	347.96	29.80	568.13	117.70	1.19	46.38	2.807	1.809
T5	479.07	34.53	636.45	172.58	1.11	37.42	2.746	1.378

The high concentrations of macro nutrients N, P, K and Ca in dry Lettuce irrigated with T5 might be due to their high concentrations in the nutrient solution used for irrigation. This might indicate that the nutrient solution concentrations affected on nutrient uptake by lettuce plant. **Samarakoon et al., 2006** showed that increasing nutrient concentration above EC level 2 dS/m increased nutrients (N, P, K, Ca) uptake by lettuce plant. On the other hand, all micro nutrient except for Cu, were high in plants irrigated with T3 may be due to high dry weight value with T3. Generally, the results of this study indicated that the contents of those essential minerals were available in the produced Lettuce around their usual level, thus, ADW can be used for irrigation when mixed with fresh water in ratio of (50% : 50%), (T3) under hydroponic conditions without any adverse effects regarding to these conditions and elements.

Heavy metals contents in lettuce plant

Application of ADW in irrigation crops usually contain elevated levels of heavy metals (specifically Cd, Ni, Cr and Pb) which might accumulate in Plants and cause toxic effects on human (**Adriano et al., 2005**). In this study, Heavy metals (Cd, Ni, Cr and Pb) concentrations in Lettuce were higher in T3 than different water treatments irrigated plants (Table 6). May be due to dry weight effect but these are below the limits set by WHO and FAO for leafy vegetables and fresh herbs (**WHO/FAO, 2007**).

Table 6. The concentration of heavy metals ($\mu\text{g plant}^{-1}$) in Lettuce plant produced under hydroponic conditions and irrigated with different water treatments.

Water Treatment	Cd	Ni	Cr	Pb
	$\mu\text{g plant}^{-1}$			
T1	0.14908	0.572	0.806	0.12399
T2	0.14514	0.790	1.153	0.13164
T3	0.16615	1.212	2.136	0.14821
T4	0.10599	1.111	1.639	0.13393
T5	0.09189	1.114	1.407	0.10373
Mean	0.13165	0.960	1.428	0.12830
Safe limits in plants (vegetative parts) (mg/l)	0.2 [†]	1.5 [‡]	20 [‡]	5.0 [†]

[†] according to WHO/FAO (2007)

[‡] according to Awashthi (2000)

CONCLUSIONS

Nutrient Film Technique (NFT) Hydroponic system is a potential technique for Lettuce production with less water consumption where water is the main limiting factor for agricultural production. Agricultural drainage water (ADW) is a feasible source for irrigation of hydroponically produced Lettuce. The current study shows the superiority of (T3) ADW mixed with fresh water in ratio 0.5/0.5 irrigated Lettuce over that irrigated with other water treatments in several aspects related to production and quality of the produced Lettuce crop. This indicated that ADW is a good source of nutrients needed for plant growth to promote high yields when mixed with fresh water T3. The accumulation of heavy metals in the Lettuce plants irrigated with ADW was apparent, yet below FAO accepted limits. The use of ADW in hydroponic systems may reduce the risk of heavy metal accumulation in the soil with prolonged use. It is also considered an environmentally sound ADW disposal practice compared to direct disposal into surface or ground water bodies. Moreover, plants irrigated with T3 used water more efficiently than those irrigated with other water treatments, Water Use Efficiency (WUE) were 16.67, 29.68, 39.96, 27.88 and 28.78 kg/m^3 for T1, T2, T3, T4, and T5, respectively. The results of this work revealed that Lettuce could be irrigated safely with agricultural drainage water (ADW) mixed with fresh

water in ratio of (50% : 50%)(T3) to produce high yield and less water use. Moreover, use of agricultural drainage water (ADW) in irrigation of Lettuce in hydroponic system considered as useful alternative disposal method of wastewater without the risk of accumulation of heavy metals in the soil.

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الملخص العربي

استخدام مياه الصرف الزراعي لإنتاج الخس في نظام الزراعة المائية

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يهدف هذا البحث إلى دراسة تأثير الري بمياه الصرف الزراعي على إنتاجية الخس وجودته وكفاءة استخدام المياه في نظام الزراعة المائية. تم استخدام ٥ معاملات خلط من مياه الصرف الزراعي مع مياه الري العادية: م١ (١٠٠٪ مياه صرف زراعي) وم٢ (٧٥٪ ماء صرف زراعي + ٢٥٪ مياه ري عادية) وم٣ (٥٠٪ ماء صرف زراعي + ٥٠٪ مياه ري عادية) وم٤ (٢٥٪ ماء صرف زراعي + ٧٥٪ مياه ري عادية) وم٥ (١٠٠٪ مياه ري عادية). تم تطوير نظام الغشاء الرقيق المغذي في الزراعة المائية ويحتوي على 5 أنابيب بي في سي وأضيف المحلول المغذي بتركيزات: ١٢.٥٪، ٢٥٪، ٥٠٪، ٧٥٪، ١٠٠٪ من المحلول المغذي القياسي وذلك للمعاملات م١، م٢، م٣، م٤ و م٥ على الترتيب لاستخدامه في هذه الدراسة. تم حصاد الخس بعد ٥٠ يوم من الزراعة بنظام الغشاء الرقيق المغذي. ووضحت النتائج ان الري بالمعاملة الثالثة م٣ ادى الى زيادة المحصول الأخضر والمادة الجافة. وكان اعلى انتاج للخس مع م٣ < م٤ < م٢ < م١ على الترتيب. والنباتات المروية بالمعاملة الثالثة م٣ استخدمت المياه اكثر كفاءة من نباتات المعاملات الاخرى واعلى قيمة لكفاءة استخدام المياه كانت ٣٩.٩٦ كجم /م^٣ مع م٣ و اقل قيمة كانت ١٦.٦٧ كجم /م^٣ مع م١. ومن الجانب الاخر فان قيم العناصر المغذية في المادة الجافة للخس (نيتروجين، فسفور، بوتاسيوم، كالسيوم) وجدت بتركيز عالى في النباتات المروية ب م٥ عنها في النباتات المروية بمعدلات المياه الاخرى. والعناصر الثقيلة (كادميوم، رصاص، نيكيل، كروميوم) كانت اعلى في م٣ عنها للنباتات المروية بانواع المياه الاخرى ولكن لم تتعدى الحدود المسموح بها طبقا لمنظمة الاغذية والزراعة للمحاصيل التي تؤكل.

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