

COMPARISON BETWEEN HYDROPONIC AND AEROPONIC SYSTEMS FOR LETTUCE PRODUCTION

Marwa M. Ali*, **El-Sayed G. Khater****, **Samir A. Ali**** and **Zakaria A. El-Haddad****

ABSTRACT

The main objective of this research is to study the effect of aeration on preventing the root problems by comparing the hydroponic system with aeration to the aeroponic system. The obtained results indicated that the root length increased from 17.17 to 19.13 cm with increasing flow rate from 1.0 to 2.0 L h⁻¹ in hydroponic system and increased from 17.45 to 19.56 cm with increasing flow rate from 0.5 to 1.5 L h⁻¹ in aeroponic system. The fresh and dry mass of shoot and root were increased in aeroponic system over those of hydroponic system. The total nutrients uptake values were higher in aeroponic system than those in hydroponic system. The average nitrogen, phosphorus, potassium, calcium and magnesium uptakes were 3.29, 1.25, 2.46, 0.43 and 0.44 % and 2.13, 0.82, 1.81, 0.32 and 0.40 % for aeroponic and hydroponic system, respectively. The average nitrate content was 155.52 and 113.73 mg plant⁻¹ for aeroponic and hydroponic system, respectively. The average nitrate protein ratio was 1.91 and 4.16%, for aeroponic and hydroponic system, respectively. The average water use efficiency was 4.75 and 2.93 kg m⁻³ for hydroponic and aeroponic system, respectively.

Keywords: Hydroponics – Aeroponics – Lettuce – Vegetative parameters – Yield

* Graduate Student of Agric. Eng. Dep., Fac. of Agric., Benha Univ., Egypt

** Fac. of Agric., Benha Univ., Egypt

1. INTRODUCTION

Lettuce (*Lactuca sativa L.*) belongs to the family Compositae which is one of the most important vegetable crops in the world. It is cultivated mainly in open fields as well as under greenhouse conditions. Simple hydroponics like trough culture and aggregate system are much used in growing lettuce (**Peiris and Weerakkody, 2015**).

In horticultural crop production, the definition soilless cultivation encompasses all the systems that provide plant management in soilless conditions in which the supply of water and of minerals is carried out by nutrient solution, with or without a growing medium (e.g. rockwool, peat, perlite, pumice, coconut fiber, etc.). Soilless cultivation systems can be divided into: i) systems in the solid medium, using a substrate to support the plants, ii) systems in the liquid medium, which do not have other media for the support of plant roots and iii) systems in the aerated medium, the roots of the plants are suspended in a closed chamber and a nutrient solution is sprayed from below (**Winsor and Schwarz, 1990**).

Hydroponic system is a method of growing plants using a mineral nutrient solution in water, without soil. In traditional agricultural methods soil is used as the medium whereby nutrients are dissolved in water, which can then be taken up by the plant roots, although the soil itself is not necessary. If nutrients are added to the water in which the plants are grown, then the soil medium is not needed. The ability to grow plants in areas where soil is not conducive for in-ground agriculture is the great advantage of hydroponics. Also, it is much more efficient in its water use as water stays in the system and can be reused, as opposed to it percolating through the soil and ultimately replenishing the groundwater reserves. Having greater control over nutrient levels results in healthier crops, fertilizers which often contribute to pollution are not used, pesticides are not needed to deal with pests, and ultimately, much higher and more stable crop yields are achieved (**Johanson, 2009**). Hydroponics has been

primarily used for crop production under controlled conditions by supplying balanced nutrients in solution (**Rana *et al.*, 2011**).

Aeroponic culture is an optional device of the soilless culture methods in growth controlled environments such as greenhouse. This method consists of enclosing the root system in a dark chamber and supplying a solution of water and mineral nutrients with a mist device. This technique has been applied successfully for the production of different horticultural species including lettuce (**Cho *et al.*, 1996**; **Gysi and von Allmen, 1997**; **He and Lee, 1998**).

Unlike hydroponic, aeroponic did not use water as growing medium. In hydroponic, plant's roots are submerged into water to get water and nutrient to support its life. But for aeroponic, the nutrient is supply through mist spray by sprinkles or nozzles to plant's roots. An aeroponic farm system can set up with a few main components like a pump, nozzles, and growing chamber. There are a few types of aeroponic currently exist like low pressure type, high pressure type and commercial system. Different type of aeroponic required different kind of component to set up but the working concept is about the same (**QI, 2012**).

Benefit of aeroponics system is that of easy monitoring of nutrients and pH. Aeroponics system provides precise plant nutrient requirements for the crop, thereby, reducing fertilizer requirement and minimizing risk of excessive fertilizer residues moving into the subterranean water table (**Nichols, 2005**). Aeroponics system also allows the measurement of nutrient uptake over time under varying conditions.

Lettuce is one of the best crops for soilless systems because it can be produced in a short period and, as a consequence, pest pressure is relatively low. Unlike tomato and cucumber, a high proportion of the harvested biomass is edible. With lettuce, income per unit area per unit time is very high. Other fast growing and high income generating

crops are herbs such as basil and chive, which are being grown commercially in soilless systems (**Rackocy and Hargreaves, 1993**).

The most severe problem in the hydroponic system is the root rot which is due to the low oxygen level in the nutrient solution, therefore, proper aeration is required to overcome this problem. Aeroponic system is the proper solution to provide the plant with the required oxygen and nutrients, so that the main aim of this work is to study the effect of aeration on preventing the root problems by comparing the hydroponic system with aeration to the aeroponic system.

2. MATERIALS AND METHODS

The experiment was carried out at Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture Moshtohor, Benha University, Egypt (latitude 30° 21' N and 31° 13' E). During the period of February and March, 2015 season.

2.1. System description

Fig. 1 illustrates the experimental setup. It shows hydroponic system, aeroponic system, solution tank and pumps.

The hydroponic system consists of nine rectangular polyethylene tanks used for lettuce plants culture. Dimensions of each tank are 80 cm long, 40 cm wide and 30 cm high. The slope of hydroponic tanks was 2 % and stand one m high above the ground. The hydroponic tanks were covered with foam boards to support the plants. Each hydroponic tank equipped with 15 W air blower of flow rate 850 L h⁻¹ at 1.5 m head to increase dissolved oxygen concentrations. The solution was circulated by a 0.5 hp pump in a closed system of flow rate 30 L min⁻¹ at 25 m head from the solution tank to the upper ends of the hydroponic tanks through a 16 mm tube to supply each tank from the bottom of each tank to the solution tank.

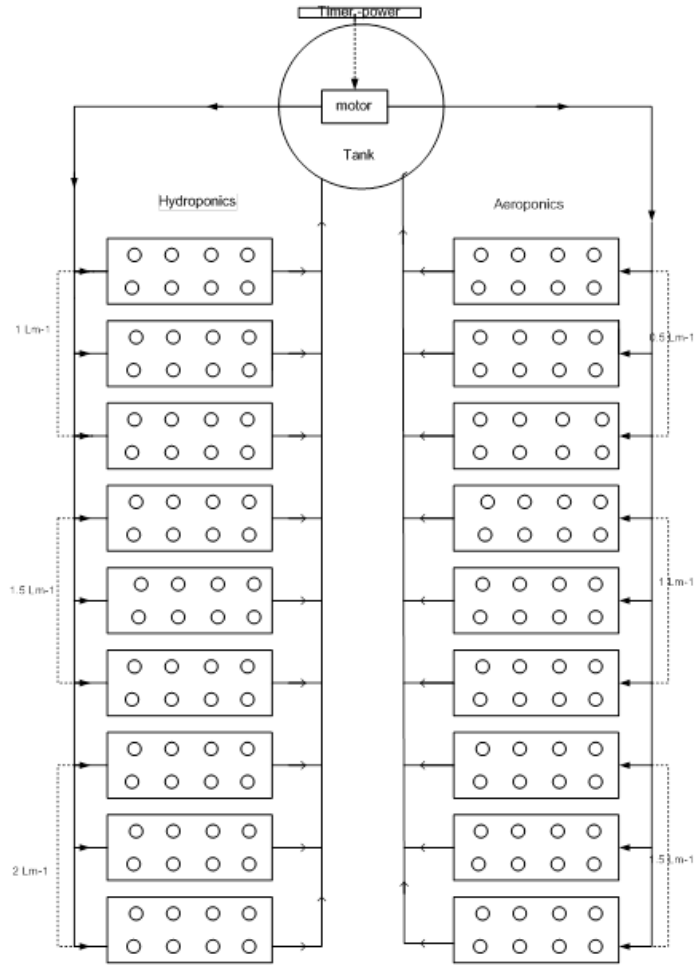


Figure (1): The experimental setup

Nine aeroponic tanks were located in the same greenhouse of a dimensions of each tank are 80 cm long, 40 m wide and 50 cm high. The aeroponic tanks were established 1 m above the ground. The aeroponic tanks covered with foam boards to support the plants. Each aeroponic tank provided by two fog nozzles located at the bottom of the tank for spraying nutrient solution inside the tank in order to keep the plant roots wet. The aeroponic tanks were divided to three groups, the first group was provided of two fog nozzles (2 L h⁻¹ discharge), the second group was provided of two fog nozzles (4 L h⁻¹ discharge) and

the third group was provided of two fog nozzles (6 L h⁻¹ discharge). Small tubes (16 mm) were used to supply each aeroponic tank with solution discharged of the solution tank in a closed system.

The circular polyethylene tank of the nutrient solution system 500 liter capacity was used for collecting of drained solution by gravity from the ends of the hydroponic and aeroponic tanks. The amount of chemicals used in the system as described by **Hoagland and Arnon (1950)**. Also a complete replacement for the nutrient solution was done every ten days.

2.2. Lettuce plants

Lettuce seedlings were sown in the plastic cups (7 cm diameter and 7 cm height) filled with peatmoss. The cups were irrigated daily using water with Hoagland and Arnon. Two weeks old lettuce seedlings were planted in the experimental tanks. The plant spacing on the row was 20 cm **Khater (2006)**.

2.3. Treatment

The treatments were arranged in randomize complete block design in three replications. Two type of soilless culture (Hydroponic system and Aeroponic system). For hydroponic system three water flow rates 1.0, 1.5 and 2.0 L plant⁻¹ h⁻¹ were considered intermittent flow 15 minute 'on' and 15 minute 'off'. For aeroponic system three water flow rates for aeroponic 0.5, 1.0 and 1.5 L plant⁻¹ h⁻¹ were considered intermittent flow 15 minute 'on' and 15 minute 'off'.

2.4. Measurements

Root length was measured every ten days. The fresh and dry mass were measured at the end of the experiment. After measured fresh mass the plants were oven dried at 70 °C until constant weight was reached. Total content of macro elements were evaluated after being digested according to Chapman and Partt (1961). Nitrogen was determined by Kjeldahl digestion apparatus (Bremmer and Mulvaney, 1982). Potassium, Calcium and magnesium were determined by

Photofatometer (Model Jenway PFP7 – Range 0 - 160 mmol L⁻¹, USA) and phosphorus (P) was determined colorimetrically following the **Murphy and Riley (1962)** method. The nitrate was evaluated after being digested and measured by using salsalic acid as described by **Chapman and Partt (1961)**.

2.5. Water use efficiency

Water use efficiency (WUE) was determined by the following formula (**Djidonou et al., 2013**):

$$WUE = \frac{CY}{CWU} \quad (1)$$

where:-

CY is the crop yield, kg plant⁻¹

CWU is the crop water uptake, m³ plant⁻¹

Crop water uptake was modelled as a function of leaf area index (LAI) and daily radiation (DR) intercepted by the crop canopy (**Massa et al., 2011**):

$$CWU = \left(\frac{\left(\frac{b_1}{24 \times 3600} \right) \cdot (1 - e^{-k_1 \cdot LAI}) \cdot \frac{DR}{\lambda \times 10^5} + b_2}{\text{No. of plants per square meter} \times 1000} \right) \quad (2)$$

where:-

LAI is the leaf area index, m² m⁻²

DR is the daily radiation intercepted by the crop canopy, W m⁻²

b₁, b₂ are the empirical constants

λ is the latent heat of water vaporization, MJ kg⁻¹

k₁ is the canopy light extinction coefficient

Daily radiation was calculated according to local weather station data, which is located in faculty farm.

The leaf area index is calculated from the following equation (**Silberbush and Ben-Asher, 2001**):

$$LAI = \frac{LAI_{\max}}{1 + k_2 e^{(-k_3 t)}} \quad (3)$$

where:

LAI_{\max} is the maximum leaf area index, $m^2 m^{-2}$

k_2 and k_3 are the coefficients of the growth functions

t is the plant age, day

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

Table (1): The parameters used in the equations.

Parameter	Units	Value	References
b_1	day^{-1}	0.946	Massa <i>et al.</i> , 2011
b_2	$L m^{-2}$	0.188	Massa <i>et al.</i> , 2011
k_1	-	0.69	Massa <i>et al.</i> , 2011
k_2	-	500	Silberbush and Ben-Asher, 2001
k_3	day^{-1}	0.53	Silberbush and Ben-Asher, 2001
LAI_{\max}	$m^2 m^{-2}$	4.8	Massa <i>et al.</i> , 2011
Λ	$MJ kg^{-1}$	2.45	Massa <i>et al.</i> , 2011

2.6. 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. Root length

Figures (2 and 3) show the root length of lettuce plants grown in hydroponic and aeroponic systems at different flow rates. The results indicate that the root length was increased in aeroponic system taller than those of hydroponic system. It could be seen that the root length increased from 17.17 to 19.13 cm after 50 days from

transplanting in hydroponic system and increased from 17.45 to 19.56 cm after 50 days from transplanting in aeroponic system. These results agreed with those obtained by **Hale *et al.* (2015)** whose found that the aeroponics produced fastest growth rates.

Also, the results indicate that the root length increases with increasing flow rate and plant age. It could be seen that when the flow rate increased from 1.0 to 2.0 L h⁻¹ plant⁻¹ in hydroponic system, the length of root significantly increased from 3.35 to 3.40 cm (1.47%) and 17.17 to 19.13 cm (10.25%) after 10 and 50 days, respectively, from transplanting. It also indicate that when the time after transplanting increased from 10 to 50 days, the length of root significantly increase from 3.35 to 17.17, 3.18 to 18.27 and 3.40 to 19.13 cm at 1.0, 1.5 and 2.0 L h⁻¹ flow rate, respectively. On the other hand, the results indicated that when the flow rate increased from 0.5 to 1.5 L h⁻¹ plant⁻¹ in aeroponic system, the length of root significantly increased from 3.31 to 3.75 cm (11.73%) and 17.45 to 19.56 cm (10.79%) after 10 and 50 days, respectively, from transplanting. It also indicate that when the time after transplanting increased from 10 to 50 days, the length of root significantly increase from 3.31 to 17.45, 3.47 to 19.17 and 3.75 to 19.56 cm at 0.5, 1.0 and 1.5 L h⁻¹ flow rate, respectively. These results agreed with those obtained by **Khater (2006) and Khater *et al.* (2015)** whose found that the length of root was increased with increasing the flow rate.

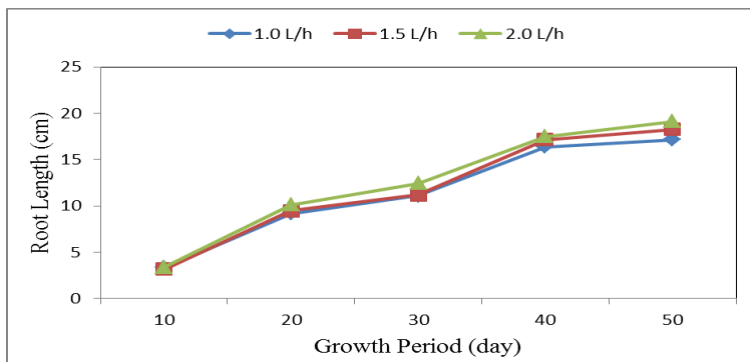


Figure (2): The root length of lettuce plants grown in hydroponic system

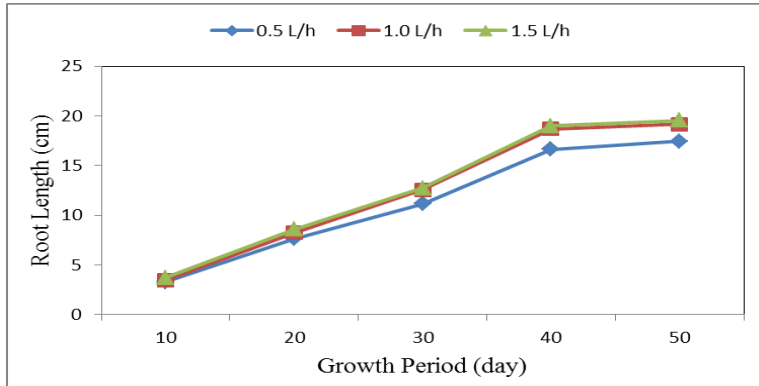


Figure (3): The root length of lettuce plants grown in aeroponic system

3.2. Fresh and dry mass

3.2.1. Fresh and dry mass of shoot

Figures (4 and 5) show the fresh and dry mass of shoot production of lettuce plants grown in hydroponic and aeroponic systems at different flow rates at the end of growing period (50 days). The results indicate that the fresh and dry mass of shoot were increased in aeroponic system over those of hydroponic system. It could be seen that the highest values of fresh and dry mass of shoot (290.84 and 39.41 g plant⁻¹) were found with aeroponic system, while, the lowest values of fresh and dry mass (134.28 and 17.52 g plant⁻¹) were found with hydroponic system. The fresh and dry mass of shoot for lettuce plants grown aeroponic system were 2.17 and 2.25 times more than those grown in hydroponic system, respectively. These results agreed with those obtained by Martin-Laurent *et al.* (1997) whose found that the Plants grown aeroponically were twice as high as those in hydroponics.

The results also indicate that the fresh and dry mass of shoot were 143.25, 222.41 and 134.28 g plant⁻¹ and 19.87, 23.41 and 17.52 g plant⁻¹ for 1.0, 1.5 and 2.0 L h⁻¹ plant⁻¹ flow rate, respectively, at hydroponic system. On the other hand, the fresh and dry mass of shoot were 290.84, 227.13 and 260.76 g plant⁻¹ and 39.41, 38.51 and 36.15 g

plant⁻¹ for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at aeroponic system. The statistical analysis showed that the interaction between both flow rate and plant age was significant.

The highest values of fresh and dry mass (222.41 and 23.41 g plant⁻¹) were obtained with a flow rate of 1.5 L h⁻¹ plant⁻¹ at hydroponic system. These results agreed with those obtained by **Khater (2006) and Genuncio (2012)** whose found that the highest values of fresh and dry mass were found with a flow rate of 1.5 L h⁻¹ plant⁻¹. While, the fresh and dry mass decreases with increasing flow rate in aeroponic system. It could be seen that when the flow rate increased from 0.5 to 1.5 L h⁻¹ plant⁻¹, the fresh and dry mass significantly decreased from 290.84 to 260.76 g plant⁻¹ (10.34%) and 39.41 to 36.15 g plant⁻¹ (8.27%). Decreasing fresh and dry mass with increasing the flow rate in aeroponic system may be due to a higher flow rates, it causes high stress on the roots causing root crushing which in turn decrease the nutrients consumption. Fresh mass of lettuce plant ranged from 134.28 to 290.84 g plant⁻¹ depending treatments under study compared to 119 to 298 g plant⁻¹ for the traditional cultivation (**Joseph et al., 2015**).

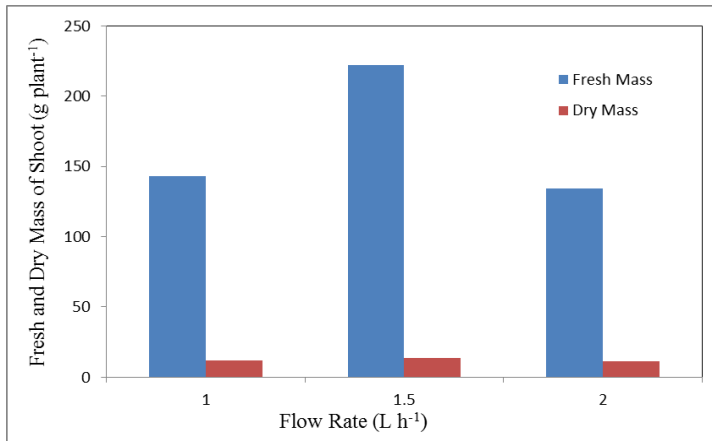


Figure (4): Fresh and dry mass of shoot production of lettuce plants grown in hydroponic system at the end of growing period.

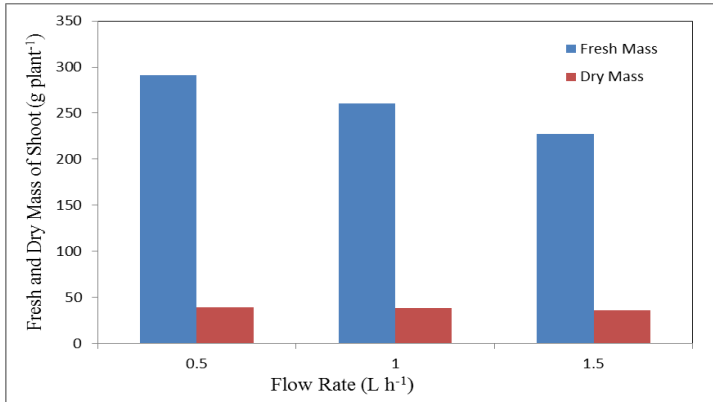


Figure (5): Fresh and dry mass of shoot production of lettuce plants grown in aeroponic system at the end of growing period.

3.2.2. Fresh and dry mass of root

Figures (6 and 7) show the fresh and dry mass of root production of lettuce plants grown in hydroponic and aeroponic systems at different flow rates at the end of growing period (50 days). The results indicate that the fresh and dry mass of root were increased in aeroponic system over those of hydroponic system. It could be seen that the highest values of fresh and dry mass of root (96.38 and 11.87 g plant⁻¹) were found with aeroponic system, while, the lowest values of fresh and dry mass of root (73.55 and 8.75 g plant⁻¹) were found with hydroponic system. These results agreed with those obtained by **Martin-Laurent *et al.* (1997)** whose found that the Plants grown aeroponically showed greater fresh and dry mass of root compared to the plants grown hydroponically.

The results also indicate that the fresh and dry mass of root were 75.63, 86.17 and 73.53 g plant⁻¹ and 9.22, 10.01 and 8.75 g plant⁻¹ for 1.0, 1.5 and 2.0 L h⁻¹ plant⁻¹ flow rate, respectively, at hydroponic system. On the other hand, the fresh and dry mass of root were 96.38, 85.09 and 79.51 g plant⁻¹ and 11.87, 10.05 and 9.71 g plant⁻¹ for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at

aeroponic system. The statistical analysis showed that the interaction between both flow rate and plant age was significant.

In hydroponic system, the highest values of fresh and dry mass of root were 86.17 and 10.01 g plant⁻¹ were obtained with a flow rate of 1.5 L h⁻¹ plant⁻¹, while, the lowest values of fresh and dry mass of root were 73.55 and 8.75 g plant⁻¹ were found with a flow rate 2.0 L h⁻¹. On the other hand, in aeroponic system, the highest values of fresh and dry mass of root were 96.38 and 11.87 g plant⁻¹ were obtained with a flow rate of 0.5 L h⁻¹ plant⁻¹, while, the lowest values of fresh and dry mass of root were 79.51 and 9.71 g plant⁻¹ were found with a flow rate 1.5 L h⁻¹. Increasing fresh and dry mass of roots was concomitant with increasing the fresh and dry mass of shoots at hydroponic and aeroponic systems may be due to increasing in nutrient consumption rate.

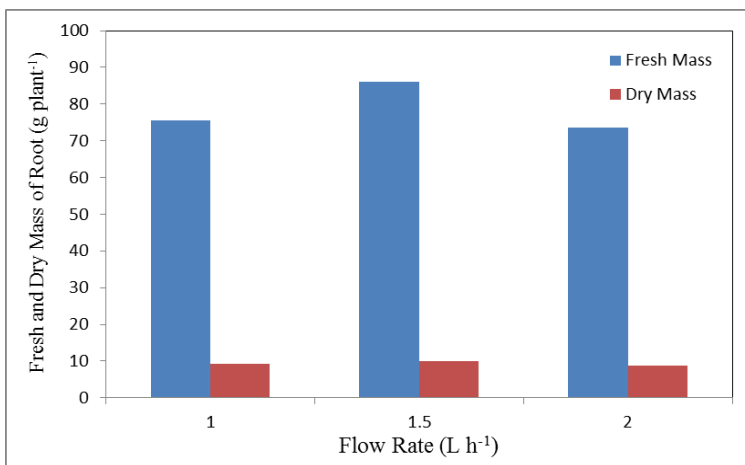


Figure (6): Fresh and dry mass of root production of lettuce plants grown in hydroponic system at the end of growing period.

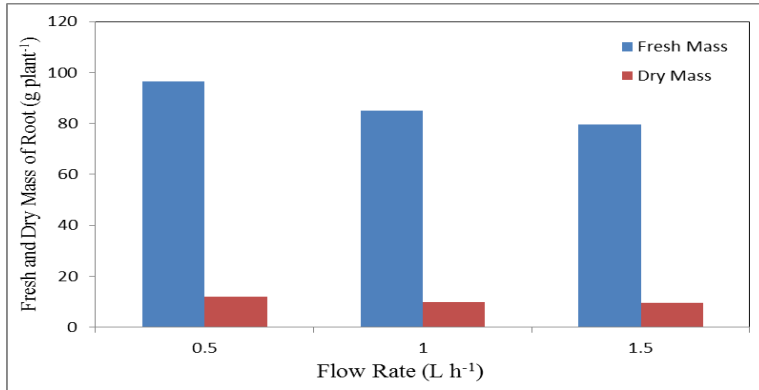


Figure (7): Fresh and dry mass of root production of lettuce plants grown in aeroponic system at the end of growing period.

3.3. Nutrients uptake

Table (2) and Figure (8) show the nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) uptake of lettuce plants grown in hydroponic and aeroponic systems at different flow rates at the end of growing period (50 days). The results indicate that the nutrients uptakes were increased in aeroponic system over those of hydroponic system. It could be seen that the N, P, K, Ca and Mg uptakes were 3.29, 1.25, 2.46, 0.43 and 0.44 %, respectively, were found with aeroponic system, while, the N, P, K, Ca and Mg uptakes were 2.13, 0.82, 1.81, 0.32 and 0.40 %, respectively, were found with hydroponic system.

The results also indicate that the nitrogen uptake was 1.96, 2.24 and 2.20 % for 1.0, 1.5 and 2.0 L h⁻¹ plant⁻¹ flow rate, respectively, at hydroponic system. On the other hand, the nitrogen uptake was 3.41, 3.24 and 3.22 % for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at aeroponic system.

The results also indicate that the phosphorus uptake increases with increasing flow rate in hydroponic system. It could be seen that when the flow rate increased from 1.0 to 2.0 L h⁻¹ plant⁻¹, the phosphorus uptake increased from 0.73 to 0.94 %. On the other hand,

the phosphorus uptake decreases with increasing flow rate in aeroponic system. It could be seen that when the flow rate increased from 0.5 to 1.5 L h⁻¹ plant⁻¹, the phosphorus uptake decreased from 1.33 to 1.10 %.

The potassium uptake was 1.81, 2.24 and 1.38 % for 1.0, 1.5 and 2.0 L h⁻¹ plant⁻¹ flow rate, respectively, at hydroponic system. While, the potassium uptake was 2.73, 2.40 and 2.26 % for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at aeroponic system.

The calcium uptake was 0.27, 0.43 and 0.27 % for 1.0, 1.5 and 2.0 L h⁻¹ plant⁻¹ flow rate, respectively, at hydroponic system. While, the calcium uptake was 0.50, 0.43 and 0.37 % for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at aeroponic system.

The magnesium uptake was 0.38, 0.41 and 0.40 % for 1.0, 1.5 and 2.0 L h⁻¹ plant⁻¹ flow rate, respectively, at hydroponic system. On the other hand, the magnesium uptake was 0.45, 0.44 and 0.42 % for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at aeroponic system.

In hydroponic system, the highest values of the N, P, K, Ca and Mg uptakes were 2.24, 0.94, 2.24, 0.43 and 0.41 %, respectively, were obtained with a flow rate of 1.5 L h⁻¹ plant⁻¹, while, in aeroponic system the highest values of the N, P, K, Ca and Mg uptakes were 3.41, 1.33, 2.73, 0.50 and 0.45 %, respectively, were obtained with a flow rate of 0.5 L h⁻¹ plant⁻¹. Increasing the nutrients uptake by lettuce plant were concomitant with increasing fresh and dry mass of shoot with a flow rate of 1.5 and 0.5 L h⁻¹ for hydroponic and aeroponic system, respectively, may be due to increasing in nutrient consumption rate. These results agreed with those obtained by **Khater and Ali (2015)**.

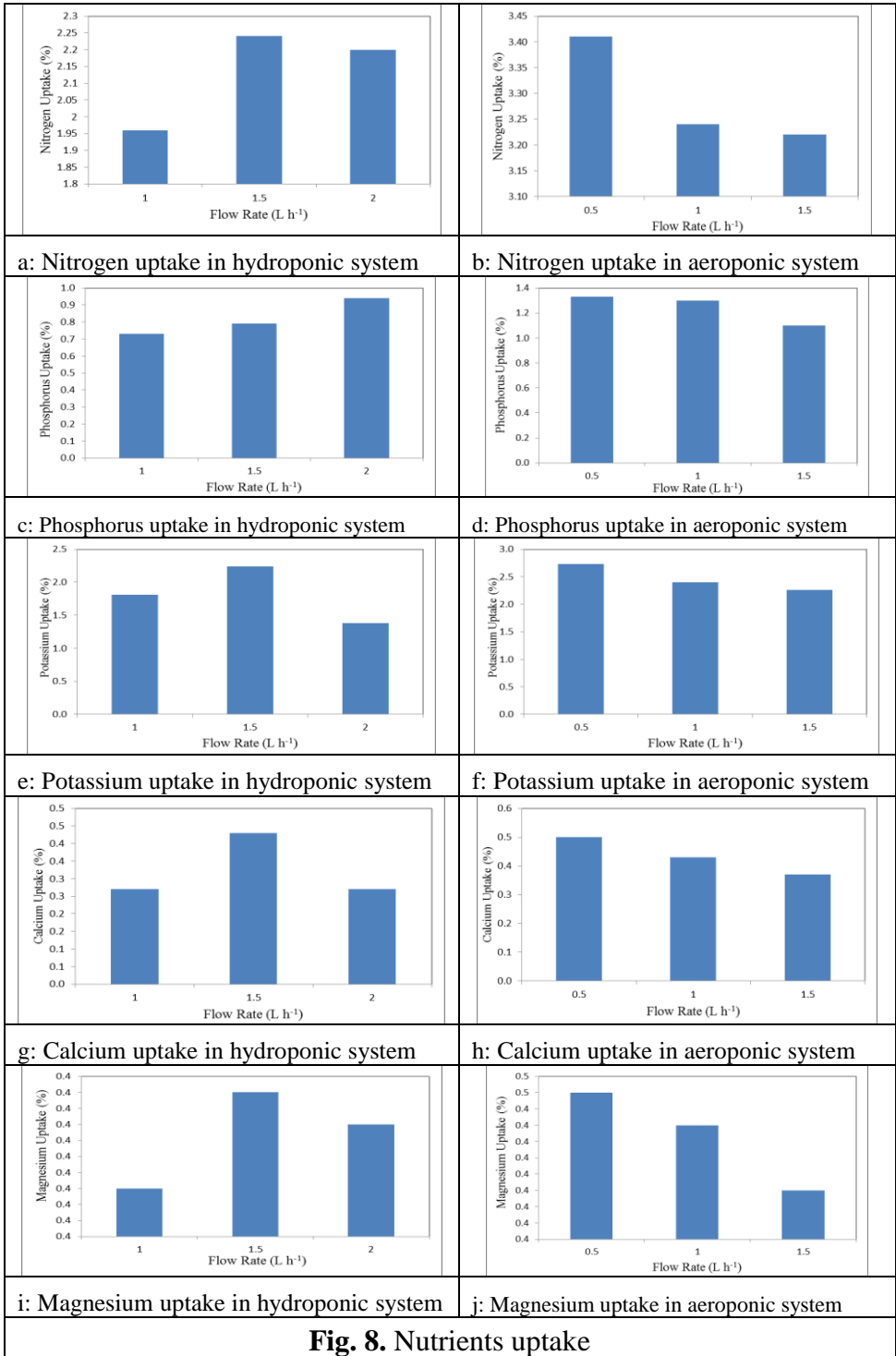


Fig. 8. Nutrients uptake

3.4. Nitrate content in plant

Figures (9 and 10) show the nitrate ($\text{NO}_3\text{-N}$) content by lettuce plants grown in hydroponic and aeroponic systems at different flow rates at the end of growing period (50 days). The results indicate that the nitrate content was increased in aeroponic system over those of hydroponic system. It could be seen that the average nitrate content was $155.52 \text{ mg plant}^{-1}$ was found with aeroponic system, while, the average nitrate content was $113.73 \text{ mg plant}^{-1}$ was found with hydroponic system.

The results also indicate that the nitrate content in lettuce plant was 112.05, 121.74 and $107.39 \text{ mg plant}^{-1}$ for 1.0, 1.5 and $2.0 \text{ L h}^{-1} \text{ plant}^{-1}$ flow rate, respectively, at hydroponic system. While, the nitrate content in lettuce plant was 159.89, 157.91 and $148.76 \text{ mg plant}^{-1}$ for 0.5, 1.0 and $1.5 \text{ L h}^{-1} \text{ plant}^{-1}$ flow rate, respectively, at aeroponic system. The statistical analysis showed that the effect of flow rate on nitrate content was significant.

In hydroponic system, the highest values of nitrate content ($121.74 \text{ mg plant}^{-1}$) were obtained with a flow rate of $1.5 \text{ L h}^{-1} \text{ plant}^{-1}$, while, in aeroponic system the highest values of nitrate content ($159.89 \text{ mg plant}^{-1}$) were obtained with a flow rate of $0.5 \text{ L h}^{-1} \text{ plant}^{-1}$. Increasing nitrate content in lettuce plant was concomitant with increasing nitrogen uptake with a flow rate of 1.5 and 0.5 L h^{-1} for hydroponic and aeroponic system, respectively, may be due to increasing in nutrient consumption rate. These results agreed with those obtained by **Khater and Ali (2015)**.

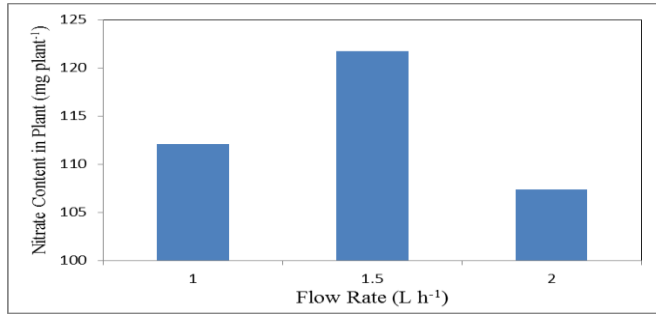


Figure (9): Nitrate content in lettuce plants grown in hydroponic system at the end of growing period.

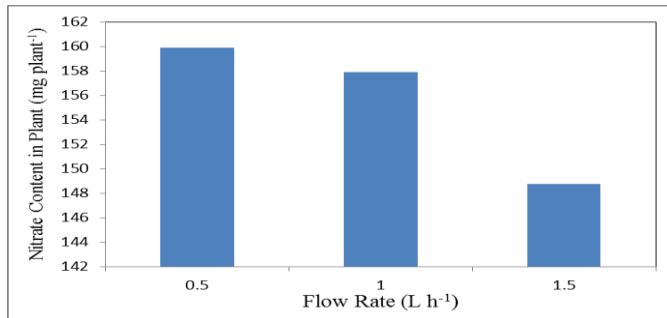


Figure (10): Nitrate content in lettuce plants grown in aeroponic system at the end of growing period.

3.5. Water use efficiency

Figures (11 and 12) show the water use efficiency for lettuce plants grown in hydroponic and aeroponic systems at different flow rates at the end of growing period (50 days). The results indicate that the water use efficiency was increased in aeroponic system over those of hydroponic system. It could be seen that the average water use efficiency was 2.22 kg m^{-3} was found with hydroponic system, while, the average water use efficiency was 3.45 kg m^{-3} was found with aeroponic system.

The results also indicate that the water use efficiency for lettuce plant was 1.90 , 2.96 and 1.79 kg m^{-3} for 1.0 , 1.5 and 2.0 L h^{-1} plant⁻¹ flow rate, respectively, at hydroponic system. While, the water

use efficiency for lettuce plant was 3.87, 3.47 and 3.02 kg m⁻³ for 0.5, 1.0 and 1.5 L h⁻¹ plant⁻¹ flow rate, respectively, at aeroponic system.

The highest value of water use efficiency was 3.87 kg m⁻³ was obtained at a flow rate of 0.5 L h⁻¹ in aeroponic system, while, the lowest value of water use efficiency was 1.79 kg m⁻³ was obtained at a flow rate of 2.0 L h⁻¹ in hydroponic system.

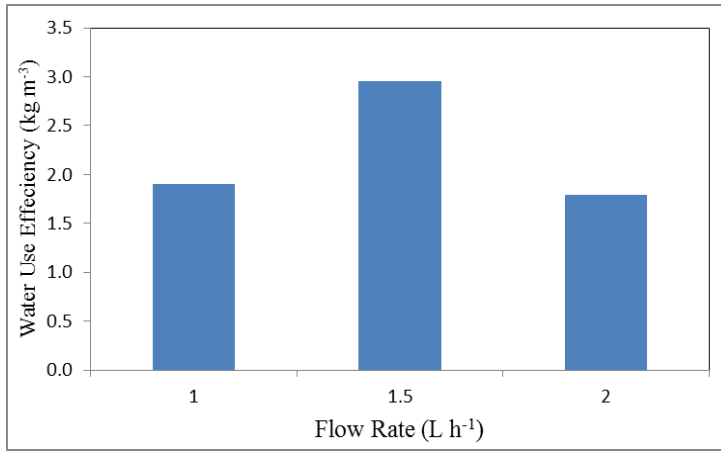


Figure (11): Water use efficiency by lettuce plants grown in hydroponic system at the end of growing period.

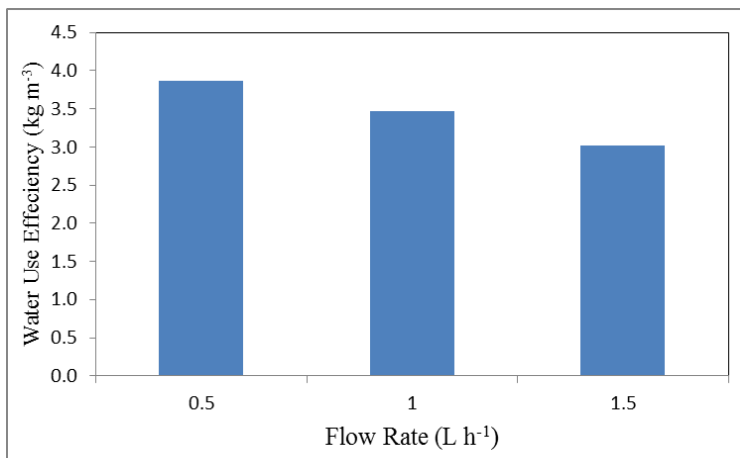


Figure (12): Water use efficiency by lettuce plants grown in aeroponic system at the end of growing period.

4. CONCLUSIONS

The experiment was carried out to study the effect of aeration on preventing the root problems by comparing the hydroponic system with aeration to the aeroponic system. The obtained results can be summarized as follows:

- The root length increases with increasing flow rate, the root length increased from 17.17 to 19.13 cm after 50 days from transplanting with increasing flow rate from 1.0 to 2.0 L h⁻¹ in hydroponic system and increased from 17.45 to 19.56 cm after 50 days from transplanting with increasing flow rate from 0.5 to 1.5 L h⁻¹ in aeroponic system.
- The highest values of fresh and dry mass of shoot were 290.84 and 39.41 g plant⁻¹ were found with aeroponic system, while, the lowest values of fresh and dry mass were 134.28 and 17.52 g plant⁻¹ were found with hydroponic system.
- The highest values of fresh and dry mass of root were 96.38 and 11.87 g plant⁻¹ were found with aeroponic system, while, the lowest values of fresh and dry mass of root were 73.55 and 8.75 g plant⁻¹ were found with hydroponic system.
- The total nutrients uptake values were higher in aeroponic system than those in hydroponic system. The average nitrogen, phosphorus, potassium, calcium and magnesium uptakes were 3.29, 1.25, 2.73, 0.50 and 0.44 % and 2.13, 0.82, 2.24, 0.43 and 0.40 % for aeroponic and hydroponic system, respectively.
- The average nitrate content in aeroponic system was 155.52 mg plant⁻¹, while, the average nitrate content in hydroponic system was 113.73 mg plant⁻¹.
- The average water use efficiency in hydroponic system was 2.22 kg m⁻³, while, the average water use efficiency in aeroponic system was 3.45 kg m⁻³.

5. REFERENCES

- Bremner, J.M., Mulvaney C.S., 1982.** Nitrogen-total. In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), *Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties*, second ed., Agronomy series No. 9 ASA, SSSA, Madison, WI, pp. 595–624.
- Chapman, H.D., Partt, F.P., 1961.** *Methods of Analysis of Soils, Plant and Water*. California University, pp. 150–200.
- Cho, Y.D., Kang S.G., Kim Y.D., Shin G.H., Kim K.T., 1996.** Effect of culture systems on growth and yield of cherry tomatoes in hydroponics. *RDA J. Agric. Sci.* 38, 563-567.
- Djidonou, D., Zhao X., Simonne E.H., Koch K.E., Erickson J.E., 2013.** Yield, water and nitrogen use efficiency in field grown grafted tomatoes. *Hort. Sci.* 48(4), 485–492.
- Genuncio, G.C., Gomes M., Ferrari A.C., Majerowicz N., Zonta E., 2012.** Hydroponic lettuce production in different concentrations and flow rates of nutrient solution. *Hort. Brasileira* 30, 526-530.
- Gomez, K.A., 1984.** *Statistical Procedures for Agricultural Research*, 2nd ed. John Wiley & Sons, New York, USA 680 pp.
- Gysi, C., von Allmen F., 1997.** Balance of water and nutrients in tomatoes grown on soilless systems. *Agrarforschung* 4:1.
- Hale, C., Lamotte F., Iannetta P., 2015.** The development of hydroponic and aeroponic culture systems for the high-throughout production of basil. www.hutton.ac.uk/webfm_send/413
- He, J., Lee S.K., 1998.** Growth and photosynthetic responses of three aeroponically grown lettuce cultivars (*Latuca sativa* L) to different root zone temperatures and growth irradiances under tropical aerial conditions, *Journal of Horticultural Science* 23, 173–180.

- Hoagland, D.R., Arnon D. I., 1950.** The water culture method for growing plants without soil. Univ. of Calif., Agric. Exp. Sta. Cir. 347 pp.
- Johanson, E.K., 2009.** Aquaponics and Hydroponics on a Budget. Tech Directions 69 (2), 21-23.
- Joseph, S.V., Bettiga C., Ramirez C., Soto-Adames F.N., 2015.** Evidence of protaphorura fimata (Collembola: Poduromorpha: Onychiuridae) feeding on germinating lettuce in the Salinas Valley of California. J. Econ. Entomol. 24, 1–9.
- Khater, E.G., 2006.** Aquaponics: the integration of fish and vegetable culture in recirculating systems. M.Sc. Thesis, in Agric. Eng., Fac. Agric., Moshtohor, Benha Univ., Egypt.
- Khater, E.G., Ali, S.A., 2015.** Effect of flow rate and length of gully on lettuce plants in aquaponic and hydroponic systems. J. Aquacult. Res. Dev. 6: 3. <http://dx.doi.org/10.4172/2155-9546.1000318>.
- Khater, E.G., Bahnasawy A.H., Shams A.S., Hassaan M.S., Hassan Y.A., 2015.** Utilization of effluent fish farms in tomato cultivation. Ecol. Eng. 83, 199 – 207.
- Martin-Laurent, F., Lee S.K., Tham F.Y., He J., Diem H.G., Durand P., 1997.** A new approach to enhance growth and nodulation of *Acacia mangium* through aeroponic culture. Biol. Fertil. Soils 25, 7–12.
- Massa, D., Incrocci L., Maggini R., Bibbiani C., Carmassi G., Malorgio F., Pardossi A., 2011.** Simulation of crop water and mineral relations in greenhouse soilless culture. Env. Model. Soft. 26, 711–722.
- Murphy, J., Riley J.P., 1962.** A modified single solution method for determination of phosphate in natural waters. Anal. Chem. Acta 27, 31–36.

- Nichols, M.A., 2005.** Aeroponics and potatoes. Proceedings of the first international symposium on root and tuber crops 'Food Down Under'. Leiden. Netherlands. Int. Soc. Hort. Sci. (ISHS). pp. 201-206.
- Peiris P. U. S., Weerakkody W.A.P., 2015.** Effect of Organic Based Liquid Fertilizers on Growth Performance of Leaf Lettuce (*Lactuca Sativa L.*). International Conference on Agricultural, Ecological and Medical Sciences (AEMS-2015) April 7-8, 2015 Phuket (Thailand).
- QI, L.J., 2012.** Development of hydro-atomized spraying system for a controlled environment aeroponic farm. Fac. Electrical Engineering, University Teknikal Malaysia Melaka.
- Rackocy, J.E., Hargreaves J.A., 1993.** Integration of vegetable hydroponics with fish culture: a review. In: Wang J.K., Ed. Techniques for Modern Aquaculture, American Society of Agricultural Engineering, St. Joseph, MI, 112-136.
- Rana, S., Bag, S.K., Golder, D., Mukherjee (Roy), S., Pradhan, C., Jana, B.B., 2011.** Reclamation of municipal domestic wastewater by aquaponics of tomato plants. *Ecol. Eng.* 37, 981–988.
- Silberbush, M., Ben-Asher J.B., 2001.** Simulation study of nutrient uptake by plants from soilless cultures as affected by salinity buildup and transpiration. *Plant and Soil* 233, 59–69.
- Snedecor, G.W., Cochran W.G., 1980. Statistical Methods, 7th Ed.,** Iowa State University Press, Ames, Iowa, USA.
- Winsor, G. W., Schwarz M., 1990.** Soilless culture for horticulture crop production. FAO Plant Production and Protection Paper, Publication No. 101, Rome, Italy.

المخلص العربي

المقارنة بين الزراعة المائية والهوائية فى إنتاج الخس

مرودة مصطفى على* السيد جمعه خاطر** سمير أحمد على** زكريا عبد الرحمن الحداد**

نظرا للمشاكل الشديدة التى تحدث فى نظام الزراعة المائية الناتجة من تعفن الجذور التى يسببها نقص مستوى الاكسجين فى المحلول المغذى، ولذلك لابد من استخدام نظام تهوية لتوفير المستوى المناسب من الاكسجين والازم لتنفس الجذور. ويعتبر نظام الزراعة الهوائية من الانظمة التى تمد النبات باحتياجاته من التهوية، ولذلك كان الهدف من هذه البحث هو دراسة تأثير التهوية للتغلب على مشاكل الجذور من خلال المقارنة بين نظامى الزراعة المائية والزراعة الهوائية لإنتاج نباتات الخس. وتم إجراء هذه التجربة فى قسم هندسة النظم الزراعية والحيوية - كلية الزراعة بمشتهر - جامعة بنها - محافظة القليوبية. وكانت أهم النتائج المتحصل عليها كما يلى:

- زاد طول المجموع الجذرى بزيادة التصرف، حيث زاد من 17.17 - 19.13 سم سم فى نهاية دورة النمو بزيادة معدل التصرف من 1 - 2 لتر/ ساعة فى نظام الزراعة المائية. وزاد من 17.45 - 19.56 سم فى نهاية دورة النمو بزيادة معدل التصرف من 0.5 - 1.5 لتر/ ساعة فى نظام الزراعة الهوائية.
- كان اعلى قيمة للوزن الطازج والجاف للمجموع الخضرى هى 290.84 و 39.41 جم/نبات خس فى نظام الزراعة الهوائية وكان اعلى قيمة للوزن الطازج والجاف للمجموع الخضرى هى 134.28 و 17.52 جم/نبات خس فى نظام الزراعة المائية.
- كان اعلى قيمة للوزن الطازج والجاف للمجموع الجذرى هى 96.38 و 11.87 جم/نبات خس فى نظام الزراعة الهوائية وكان اعلى قيمة للوزن الطازج والجاف للمجموع جذرى هى 73.55 و 8.75 جم/نبات خس فى نظام الزراعة المائية.
- زاد معدل امتصاص العناصر فى نظام الزراعة الهوائية عن الزراعة المائية، وكان متوسط بامتصاص كلا من النيتروجين والفسفور والبوتاسيوم والكالسيوم والماغنسيوم لنباتات الخس هو 3.29 و 1.25 و 2.73 و 0.50 و 0.44% على الترتيب فى نظام الزراعة الهوائية و 2.13 و 0.82 و 2.24 و 0.43 و 0.40% على الترتيب فى الزراعة المائية.
- كان متوسط محتوى نبات الخس من النترات هو 155.52 و 113.73 مجم/ نبات على الترتيب فى نظام الزراعة الهوائية والمائية.
- كان متوسط نسبة النترات للبروتين فى نبات الخس هى 4.16 و 1.91% على الترتيب فى نظام الزراعة الهوائية والمائية.
- كان متوسط كفاءة استخدام المياه نبات الخس هى 2.93 و 4.75 كجم م³ على الترتيب فى نظام الزراعة الهوائية والمائية.

* طالب دراسات عليا - كلية الزراعة بمشتهر - جامعة بنها

** كلية الزراعة بمشتهر - جامعة بنها