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EFFECT OF CULTURE SYSTEM; AERPONIC, HYDROPONIC AND SANDY SUBSTRATE ON GROWTH, YIELD AND CHEMICAL COMPOSITIONS OF LETTUCE

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Abstract

The experiment was conducted to evaluate growth, yield and chemical compositions of lettuce cultivar fire red under different culture systems hydroponic, aeroponic and sandy substrate. This experiment was conducted at the greenhouses of vegetable crops department, faculty of agriculture, Cairo University, Giza, Egypt. The systems were constructed at controlled experimental fiberglass greenhouse. The number of leaves was highest in hydroponic system compared with in aeroponic and sandy substrate systems after 2, 4 and 6 weeks of transplanting. On the other hand, the aeroponic system produced the tallest lettuce plants after 4 and 6 weeks of transplanting. Also, the aeroponic plants root length exceeded significantly roots length at the other culture systems. The root length of aeroponic was higher than the sandy substrate and hydroponic with 67.5 and 62.0 %, respectively. Hydroponic system produced the highest shoots fresh weight and yield. The yield of hydroponic system has risen 2.51 fold than the yield of sandy substrate. While the raise in yield of aerponic system in compared with the yield of sandy substrate reached to 2.30 fold. Roots fresh and dry weight in aeroponic was the highest among all systems. Sandy substrate recorded the highest plant dry matter after 6 weeks of transplanting. On the contrary, the sandy substrate recorded the lowest N, P and K % compared with aeroponic and Hydroponic systems while the highest N, P and K % was at lettuce in hydroponic system.

Key words : Hydroponic, Aeroponic, *Lactuca sativa*, root length and Yield.

Introduction

Lettuce (*Lactuca sativa* L.) is one of the most common and popular vegetables worldwide. It is belonging to family Asteraceae (or, alternatively, Compositae). The edible parts at lettuce are leaves. Lettuce contains several dietary minerals important for human's nutrition such as zinc (Zn), calcium (Ca), iron (Fe), phosphorus (P), magnesium (Mg), manganese (Mn), and potassium (K) and other health-promoting bioactive compounds (Barry, 1996 and Kim *et al.,* 2016). China is the top world producer of lettuce, the majority of the crop is consumed domestically. Spain is the world's largest exporter of lettuce, with the US ranking second. Western Europe and North America were the original major markets for wide-scale lettuce production (FAOSTAT, 2018).

In Egypt, lettuce is one of the most important vegetable crops. It has been cultivated for local consumption and exportation. It is a winter season crop. It is cultivated by seedlings and it is transplanting starting from October to February. In addition to summer production with cultivars tolerant to high temperature. The acreage of lettuce in Egypt was 6419 feddan in 2017, while the production was 59023 tonness in the same year with average yield 9.19 tons per feddan. The exportation quantity was raised from 5164 tonnes in 2012 to 13549 tonness in 2015 (FAO statistics division, 2019).

Soilless culture is a system which plants grow in the absence of soil. The nutrient solutions are providing plants with support and a reservoir for nutrients and water. It is including hydroponics, aeroponics or aquaponics systems, in addition to sand culture which sometimes considered a type of soilless culture (Graves, 1983). Nowadays, there is a great concern about conservation of the environment and natural resources, which is a key factor to ensure sustainability. So that there is a great demand to implement a new agricultural techniques and strategies which preserve the environmental and limited natural resources

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(Carvalho *et al*., 2015). Soilless culture is considered as new agricultural strategies which help to save the limited water and irrigation resources (Raviv and Lieth, 2008). Hydroponic is a technique in which plants are culturing in aqueous nutrient solutions instated of the soil (Fonts, 1973 and Resh, 1997). Also, in another definition it is a technology for growing plants in nutrient solutions (water with micro and macro elements)with or without using artificial substrate (sand, peat, gravel, perlite, vermiculute or rokwool) (Lakkireddy *et al.*, 2012). Aeroponic is defined as a technique which roots are continuously or discontinuously in a chamber or container under saturated mist or fog of nutrient solution. The method requires no substrate and the plants are growing with their roots periodically wetted with fine mist (Lakkireddy *et al.*, 2012). Hydroponic and aeroponic systems play an important role for commercial food production. So that this experiment aimed to evaluate growth and yield of lettuce cultivar fire red under different culture systems Hydroponic, aeroponic and sandy substrate.

Materials and Methods

Cultivation systems

The experiment was conducted at the greenhouses of vegetable crops department, Faculty of agriculture, Cairo University, Giza, Egypt. The systems were constructed at controlled experimental fiberglass greenhouse (demission's) which was provided with fans and pads system. The temperature was 22± 2$^{R”}$ C and the greenhouse was provided with cool white illumination system.

The Nutrient film technique (NFT) hydroponic system consisted of polyvinyl chloride (PVC) tubes. The hydroponic system unit was built in an A- frame shape at 120 cm height, 250 cm long and 100 cm wide and it was cultivated at both sided. The tubes were suspended horizontally one above the other, up to 3 levels. It was configured to move the nutrient solution in a closed system circles. It used Watt submersible pump to lift the nutrient solution from the tank (50 l) to the uppermost growing tubes. The nutrient solution was entered from the high end and slope slowly during the PVC tube and collected to back to the reservoir from it was pumped. The planting density was 25 plants per $m^{2.}$ The plants were supported at the holes of tube by sponges which surrounded the stem of seedlings and the sponges were glued at the PVC tubes (Fig. 1).

The aeroponics unit was constructed in a Styrofoam parallel rectangles with 55 cm height, 200 cm length and 100 cm width. The surface was covered with Styrofoam cover which was with holes for planting lettuce seedlings. The lettuce seedlings were supported at holes with sponges. The planting density was 25 plant per $m^{2.}$ Two hoses were entered horizontally at the parallel rectangles and there were 10 nozzles at m^2. The solution was drainage again at the tank in a closed system. It used submersible pump to lift the nutrient solution from the tank (50 l) to the uppermost growing aeroponics system (Fig. 2).

The sandy substrate culture system was conducted by using pvc pots, which were (25cm diameter). One plant was planted at each pot with 25 plants per $m^{2.}$ The substrate was 100 % sand. The pots were irrigated by the same nutrient solution which was used at the other systems.

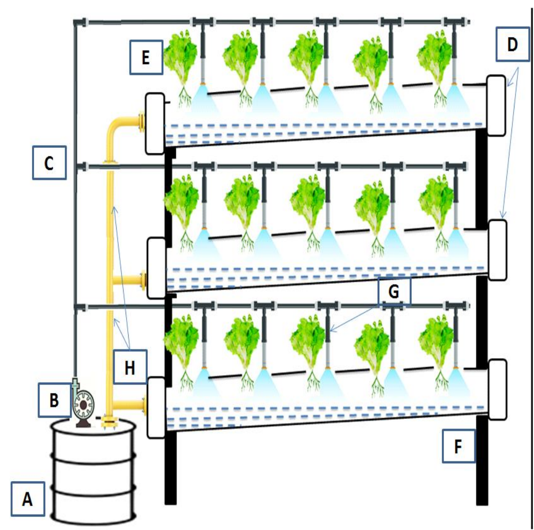

Fig 1. The outline of Hydroponic system in the experiment captions A – solution tank B- submersible pump C- main irrigation hoses D- PVC tubes E- lettuce plant F- A-frame metal stand G- submain irrigation tube H- drainage.

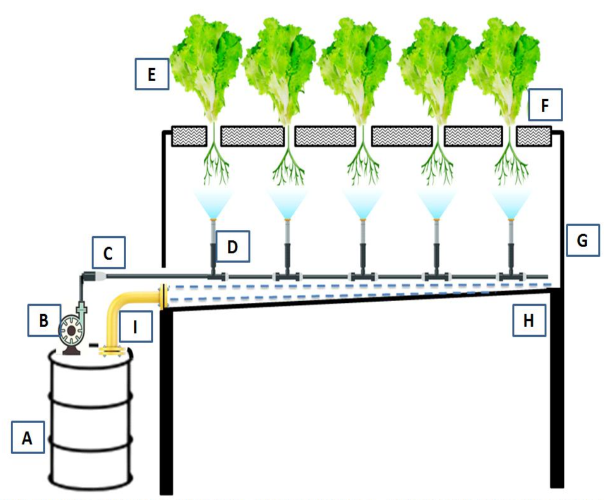

Fig 2. The outline of Aeroponic system in the experiment captions A – solution tank B- submersible pump C- main irrigation hoses D- nozzle E- lettuce plant F- Styrofoam cover G- Styrofoam parallel rectangles H- metal stand I- drainage.

Planting materials

The lettuce (*Lactuca sativa*) cv. Red fire seedlings were transplanted at the all systems at the third week of

January 2018. Before the transplanting, the seedling's roots were washed gently with tap water to remove the culture mixture. After the transplanting, the plants at all systems were supplied with diluted solution of Cooper's nutrient solution (one liter of solution A and B of Cooper solution per 100 liters of water) which, consisted of (mg L -1) N-236, P 60.0, K 300, Ca 185, Mg 50, S 68, FE (EDTA) 12, Mn 2.0, Zn 0.1, Cu 0.1, B 0.3, Mo 0.2 (Cooper, A. 1988). The experiment was repeated twice in a Completely Randomize Design (CRD).

Measurements

Six plants from each system were selected from each system in 2,4 and 6 weeks (at harvest) from transplanting to measured number of leaves and plant height meanwhile, at harvesting (6 weeks from transplanting) fresh and dry weight of shoots, roots, root length and dry matter % were measured whereas, the roots were washed gently with tap water to remove any substrate residues. Then the plants were dried gently by towels to remove the moisture. Shoots and roots fresh weights were recorded. The shoots and roots samples were dried at oven on $70^{R''}$ c for 72 hours. The plant dry matter % was calculated as (plant dry weight/ plant fresh weight) × 100. The root/ shoot ration was calculated as the root dry weight/ shoot dry weight (Li *et al.,* 2018). The yield of m^2 was recorded for all systems.

Chemical compositions

Chlorophylls determination at green leaves

Chlorophyll a, Chlorophyll b, Total Chlorophyll and Carotenoids were extracted by *N, N*-dimethylformamide from green leaves after 2, 4 and 6 weeks of culture and determinate according to (Moran, 1982)

Total nitrogen

Determination of total nitrogen was carried out with Micro-Kjeldahel method at dried samples after 6 weeks of transplanting. (AOAC, 1990).

Phosphorus

The total phosphorus in different samples was extracted as reported by Soltanpour (1985) and spectrophotometrically determined according to procedures of Olsen and Watanab (1965).

Potassium

The total potassium in tested samples was determined by Flame photometric according to APHA method (APHA, 1992).

Statistical analysis

Regular analysis of variance of Completely Randomized Design (CRD) with 6 replicates was performed for the obtained data. Differences between means were compared to the estimated value of L.S.D at 5% level of probability (Snedecor and Cochran, 1982).

Results and Discussion

The effect of culture system (sandy substrate, aeroponics and hydroponics) on number of leaves and plant height of lettuce is shown at table 1. Data showed that the number of leaves at aeroponic and hydroponic systems was significantly higher than the values at plants grew in sandy substrate after 2, 4 and 6 weeks of transplanting. After 2 weeks of transplanting, the percentages of increment were 78.4 and 61.12% in hydroponic or aeroponic systems, respectively in compared with the number of leaves at sandy substrate. On the other hand, there was no significant difference between the hydroponic and aeroponics after 2 weeks of transplanting. While after the fourth week of transplanting, hydroponic plants showed significantly the highest number of leaves with raises reached up to 10.8 and 33.3% than number of leaves at aeroponics and sandy substrate plants, respectively. At the end of the experiment, no significant difference was recorded between the number of leaves of hydroponics and aeroponics plants. On the other hand, both of them were significantly higher than the number of leaves at sandy substrate plants with percentages of increment recorded 26.7 and 20.37% at hydroponics and aeroponics, respectively. In conclusion, during the three periods, the number of leaves at hydroponics plants was higher than the other culture systems. This in agreement with Li *et al.* (2018), they found that the lettuce grown in hydroponic had a larger shoots growth compared with aeroponic and substrate cultivation systems.

Data in table 1 show that after 2 weeks of transplanting, the hydroponic system produced the highest plants in compared with the other culture systems. These differences between the three culture systems on plant height were not significant. Meanwhile after 4 weeks of transplanting, the maximum lettuce plant height was produced at aeroponic system. These differences were significant in compared with the plants height at other systems. At the same period, the hydroponic plants were at the second rank of plant height. The aeropoinc plants recorded raises in plant height were 9.7 and 18.62% higher than the hydroponic and sandy substrate plants, respectively. The same trend appeared after 6 weeks of transplanting, that the aeroponic plants were the highest plants in compared with the other systems. This agree with which reported by Martin-Laurent *et al.,* (1997) whose found that the plants grown aeroponically were

Table 1: Effect of culture system (sandy substrate, aeroponics and hydroponics) on number of leaves and plant height of lettuce after 2, 4 and 6 weeks of transplanting.

Culture System	No. of leaves			Plant height (cm)		
	2 weeks	4 weeks	6 weeks	2 weeks	4 weeks	6 weeks
Sandy substrate	5.17 B	9.00C	13.67B	13.25 A	18.17C	19.77 B
Aeroponics	8.33 A	10.83B	17.17 A	13.50A	22.33A	26.83A
Hydroponics	9.17 A	12.00A	17.33 A	14.50 A	20.17B	26.78 A

Means in the same column followed by the same letter/s are not statically different at 0.05 % of probability.

Table 2: Effect of culture system (sandy substrate, aeroponics and hydroponics) on fresh and dry weight of shoots, plant dry matter, root length and fresh and dry weight of roots at harvest (6 weeks of transplanting).

Culture System	Shoots fresh weight (g)	Shoots dry weight(g)	Roots fresh weight(g)	Roots dry weight(g)	Plant dry matter %	Root length(cm)
Sandy substrate	39.17 B	3.12 B	5.00 B	0.48 B	8.14 A	30.20B
Aeroponics	90.37 A	4.49 A	15.99 A	0.85 A	5.04 B	58.73A
Hydroponics	98.54 A	4.41 A	14.52 A	0.73 A	4.60 B	36.25B

Means in the same column followed by the same letter/s are not statically different at 0.05 % of probability.

twice as high as those in hydroponics. No significant difference recorded between the aerponics and hydroponics plants. Although, the plants derived from sandy substrate system were significantly the shortest plants among the three systems. These previous results may be due that the roots of aeroponics systems are hanged in mid-air inside containers or chambers at 100 % humidity and fed up a fine mist of nutrient solutions. This pervious system stimulates absorption of roots to much needed oxygen and nutrients, those increasing metabolism and rate of growth compared with soil (Runia, 1995 and Lakkireddy *et al.*, 2012).

The effect of culture system (sandy substrate, aeroponics and hydroponics) on fresh and dry weight of shoots, plant dry matter, root length and fresh and dry weight of roots at harvest (6 weeks of transplanting) is shown at table 2. The shoots fresh weight of hydroponics plants was the highest among the culture systems. No significant difference was detected between the hydroponic and aeropoinc systems. Even though, both systems recoded shoots fresh weight of lettuce folded 2.51 and 2.30 at hydroponics and aeroponics systems respectively, than the lettuce fresh weight at sandy substrate. The previous trend was observed at shoots dry weight. It is noticeable that no significant difference was recorded between the shoots dry weights of hydroponic and aeropoinc plants. Although, the dry weight of both of them were significantly higher than the dry weight of sandy substrate plants. The same results were mentioned by Li *et al.,* (2018) that they reported that the shoots fresh and dry weights of hydroponic lettuce at the both tested lettuce cultivars were folded twice than the aeroponics and substrate plants. The reason of the hydroponics and aeroponics superiority in plants fresh weight may be refer to their growth touched at high content of water in compared with the sandy substrate and this lead to sufficient water supply to the roots and the plants. In addition, increasing the yield of hydroponics to leafy crops e.g. lettuce and chicory, Treftz and Omaye (2015) found that the hydroponic strawberries had a 17% higher yield compared with the soil grown strawberries. This findings may be refer to that the plants in hydroponic systems are grown at precise control over the nutrient solution and the ability of them to be in their the most favorable growing conditions. The roots fresh and dry weights of aeroponic plants recorded the highest values among all the culture systems. These values reached to 3.2 and 1.8 fold in compared with the values of fresh and dry weight of the sandy substrate. This can be relating to that the aeroponic plants produced the tallest roots among the other systems. These results agreed with those reported by Martin-Laurent *et al.,* (1997) they found that the plants grown aeroponically showed greater fresh and dry mass of root compared to the plants grown hydroponically. We can explain those that the aeroponic system enhance the rates of plants growth by promoting the root aeration because of the root system is grown totally suspended at the air, giving the plant stem and roots systems access to 100% of the available oxygen at the air (Buckseth *et al.,* 2016). On the other hand, no significant differences were detected between the roots fresh and dry weights of hydroponic and aeroponic systems. On the other hand, both of them were significantly higher than the sandy substrate plants at roots fresh and dry weights. This may be related that the hydroponic and aeroponic plants have a higher content of water in compared with the plants which were grown at sandy substrate. This higher content of water may be refer to the continuously growth at nutrient solutions. So that the same trend was detected either at fresh weights or dry weights of shoots and roots.

The sandy substrate plants showed significantly the highest plant dry matter percentage among the culture systems. On the contrary, the hydroponic recorded the lowest plant dry matter but without significant difference with the aeroponic system. The plant dry matter of sandy substrate show increase reached to 1.77 and 1.62 fold in compared with plant dry matter of hydroponic and aeroponics, respectively. These results are expected at the plants dry matter of sandy substrate because of its low content of water in compared with the other systems of soilless cultures.

The aeroponic plants root length exceeded significantly roots length at the other culture systems. The root length of aeroponic was higher than the sandy substrate and hydroponic with 67.5 and 62.0 %, respectively (Fig. 3). On the other hand, no significant difference was recorded at the root length of hydroponic and sandy substrate systems. Many studies showed that the aeroponic system enhance the rates of plants growth by promoting the root aeration because of the root system is grown totally suspended at the air, giving the plant stem and roots systems access to 100% of the available oxygen at the air (Mehandru *et al.,* 2014 and Buckseth *et al.,* 2016). These results are in agreement with findings which were reported by Li *et al.*, (2018) that they showed that lettuce root length, area, volume of aeroponic system were significantly exceeded the hydroponic and substrate systems. Also at the one of their tested lettuce cultivars (Dasusheng) root length, area, volume of aeroponic system were four to five times that of the hydroponic and substrate systems.

Table 3 shows the effect of culture system (sandy substrate, aeroponic and hydroponic systems) on yield/ $m^{2,}$ shoot/root ratio, N, P and K % of lettuce after 6 weeks of transplanting. The yield of lettuce/ m^2 was higher at the hydroponic system in compared with the other systems. Either the lettuce yield at hydroponic system or aeroponic was significantly higher than the yield of the sandy substrate. No significant difference was detected between the yield of hydroponic and aeroponic systems. The yield of hydroponic system has risen 2.51fold than the yield of sandy substrate. While the raise at yield of aerponic system in compared with the yield of sandy substrate reached to 2.30 fold. The yield superiority of hydroponic and aeroponic systems may be referring to the high content of water at plants. The low plants dry

Fig 3. Lettuce plants in (a) aeroponic system, (b) hydroponic system and (c) sandy substrate.

matter at both systems (hydroponic and aeroponic) in compared with the sandy substrate confirms the possibility of this explanation. In addition that the hydroponic which recorded high yield of lettuce was the lowest system at plant dry matter. The same results were obtained by Li *et al.,* (2018); they reported that the lettuce in hydroponic systems produced the highest plant fresh weight and yield compared with aeroponics and substrate systems. Also, the yield of hydroponically lettuce exceeded the yield in aeroponics and substrate with 1.8 and 2.4 fold, respectively at only one of their tested cultivars. And at the second cultivar (Dasusheng) the increases recorded 2.3 and 1.8 fold at aeroponics and substrate, respectively.

The root/shoot ratio at aeroponic plants was highest than the other systems. On the contrary, the sandy substrate recorded the lowest value of shoot/root ratio. Although all of these values recorded no significant differences. These findings agree with Li *et al.,* (2018) they showed that there were differences between their three growing cultures (aeroponics, hydroponics and substrate) at root/shoot ratio of the two tested cultivars. That the root / shoot ratio of aeroponic was almost higher three times than the hydroponic lettuce, and was also significantly higher than the value at substrate culture. Even though their results were clearer than ours.

The nitrogen percentage (N%) at leaves after 6 weeks of transplanting was highest at hydroponic system in compared with the other systems. This value is not significantly differing than the N% at the aeroponic lettuce. On the other hand, the percentages of N at hydroponic and aeroponic systems were significantly higher than the N % of sandy substrate. The increments of N percentages recorded 2.33 and 2.07 fold at hydroponic and aeroponic system, respectively in compared with the sandy substrate. The pervious obtained

Table 3: Effect of culture system (sandy substrate, airoponics and hydroponics) on yield/m^2 , shoot/ root ratio, N, P and K % of lettuce after 6 weeks of transplanting.

Culture System	Yield/m^2(g)	Root/shoot Ratio	Nitrogen (N %)	Phosphorus (P %)	Potassium (K %)
Sandy substrate	979.21 B	0.16 A	1.58 B	0.215 B	7.27 B
Aeroponics	2259.33 A	0.19 A	3.28 A	0.625 A	10.97 A
Hydroponics	2463.62 A	0.17 A	3.69 A	0.708 A	11.25 A

Means in the same column followed by the same letter/s are not statically different at 0.05 % of probability.

results agree with Li *et al.,* (2018), they reported that at their both tested cultivars, the leaf N content in hydroponic lettuce was significantly higher than that of aeroponic and substrate. The percentage of phosphorus at sandy substrate was significantly lower than the P% of lettuce leaves at hydroponic and aeroponic systems. On other hand, the hydroponic system recorded the highest percentage of phosphorus in compared with the other systems. The increases reached up to 3.29 and 1.13 fold than the sandy substrate and aeroponic, respectively. No significant difference was recorded between the hydroponic and aeroponic systems at P %. Li *et al.,* (2018) reported the same findings, which the leaf P content of hydroponic lettuce was significantly higher than that of the aeroponic and substrate cultivated lettuce. Hydroponic system showed the highest percentage of potassium at lettuce leaves after 6 weeks of transplanting among all systems. The difference between the hydroponic and aeroponic was not significant. On the other hand, the both systems were significantly higher than the sandy substrate in P%. This raises recorded 54.74 and 50.89% at hydroponic and aeroponic respectively in compared with the plants grew at sandy substrate. The pervious obtained results agree with Li *et al.,* (2018), they reported leaf K content of both aeroponic and hydroponic was significantly higher than that in substrate cultivated lettuce, however there were no significant differences between the hydroponic and aeroponic. The high content of hydroponically lettuce of N, P and K may refer to that the plants are growing continuously at the solutions contains the nutrients however; this property is not available at sandy substrate and aeroponic culture systems.

Effect of culture system (sandy substrate, airoponics and hydroponics) on Chlorophyll.a (Chl.a), Chlorophyll.b (Chl.b) and total Chlorophyll (Total chl.) mg/g fresh weight of lettuce after 2,4 and 6 weeks of culture are shown at table number 4. After 2 weeks of transplanting, the leaves samples of aeroponic system showed the highest content of chl.a, chl.b and total chl in compared with the leaves of hydroponic and sandy substrate. The differences between the hydroponic and aeroponic at content of chl.a, chl.b and total chl were not significant. On the other hand, the content of chl.a, and total chl. at leaves of sandy substrate was significantly lower than aeroponic system however; these differences were not significant between the hydroponic and sandy substrate systems. The sandy substrate showed the lowest chl.b content in compared with the other systems.

After 4 weeks of transplanting, no significant differences were detected among systems at chl.a content. Meanwhile, the chl.a content of sandy substrate leaves was higher than chl.a content at aeroponic and hydroponic systems. These increments were 27.17 and 20.35% at aeroponic and hydroponic, respectively in compared with the substrate system. The content of chl.b at lettuce of sandy substrate was the highest compared with other systems. No significant differences were recorded in chl.b content of substrate system compared with aeroponic system. The increments of chl.b content in substrate system were 65.62 higher than aeroponic. Also the aeroponic and hydroponic systems were not recorded significant differences between each other. The same trend was noticed at total chl. That the content of total chl. Of aeroponic leaves was significantly lower than the content of sandy substrate. On the other hand, no significant differences were recorded between total chl. content of aeroponic and hydroponic systems. Mean while the hydroponic leaves showed higher total chl. content than aeroponic. The content of total chl. at hydroponic leaves was 0.35 mg/g fresh weight while the

Table 4: Effect of culture system (sandy substrate, airoponics and hydroponics) on chlorophyll.a (Chl.a), chlorophyll.b (Chl.b) and total chlorophyll (total chl.) (mg/g fresh weight) of lettuce after 2, 4 and 6 weeks of transplanting.

Culture system	2 weeks			4 weeks			6 weeks		
	chl.a	chl.b	total chl.	chl.a	chl.b	total chl.	chl.a	chl.b	total chl.
Sandy Substrate	0.25 B	0.06 B	0.30 B	0.34 A	0.16 A	0.50 A	0.40 A	0.16 A	0.56 A
Aeroponics	0.39 A	0.18 A	0.57 A	0.25 A	0.05 B	0.28 B	0.43 A	0.14 A	0.56 A
Hydroponics	0.27 AB	0.14 A	0.41 AB	0.27 A	0.10 AB	0.34 AB	0.27 A	0.11 A	0.39 A

Means in the same column followed by the same letter/s are not statically different at 0.05 % of probability.

Table 5: Effect of culture system (sandy substrate, airoponics and hydroponics) in total Carotnoids (mg/g fresh weight) of lettuce after 2, 4 and 6 weeks of culture.

Culture system	After 2 weeks	After 4 weeks	After 6 weeks
Sandy substrate	0.105 A	0.051 A	0.050 B
Aeroponics	0.032 B	0.062 A	0.067 A
Hydroponics	0.044 B	0.055 A	0.049 B

Means in the same column followed by the same letter/s are not statically different at 0.05 % of probability.

content of aeroponic was 0.28 mg/g fresh weight. In addition to the above the content of total chl at sandy substrate leaves was higher than at hydroponic system. This increase reached to 30.9% but without significant differences.

After 6 weeks of transplanting, the contents of chl.a and total chl. were the highest at aeroponic lettuce compared with the other culture systems. The increases of chl.a at aeroponic were reached to 6.75 and 39.56% higher than the content in leaves of sandy substrate and hydroponic, respectively. In addition to the above, the increments at total chl. content in aeroponic system recorded 0.53 and 31.03% higher than the content in leaves of sandy substrate and hydroponic, respectively. However the chl.b was the highest content in sandy substrate among all systems. Also, the values of chl.a, chl.b and total chl were the lowest at the lettuce in hydroponic compared with the other two systems. Despite all the above, there were no significant differences among all systems at chl.a, chl.b and total chl content after 6 weeks of transplanting. The pervious findings may be refer to that the grown lettuce at hydroponic was in a high and touched content of water in compared with the other systems. So that the pigments content probably were decreased by increasing the total water content of hydroponic lettuce. Also, we can relate this explanation with the total plant dry matter. It is shown at table no 2 that the lettuce plant dry matter in hydroponic system was lower than it at sandy substrate and aeroponic.

Table 5 shows the effect of culture system (sandy substrate, airoponics and hydroponics) in total carotnoids (mg/g fresh weight) of lettuce after 2, 4 and 6 weeks of transplanting. Firstly after 2 weeks of transplanting, total carotnoids content in sandy substrate lettuce was significantly the highest among all systems. The contents of total carotnoids in lettuce at sandy substrate were folded 3.3 and 2.9 higher than it in aeroponic and hydroponic, respectively. The content of lettuce total carotnoids in hydrponic system was higher than it in aeroponic however, no significant differences were recorded between both systems. These results were contrariwise with our findings about contents of chl.a, chl.b and total chl. effects by culture systems. This refers to reverse relationship in leaves contents of chl.a, chl.b and total chl. with total carotnoids content. After 4 weeks of transplanting, no significant differences were detected among all culture systems in total carotnoids. Mean while, the content of total carotnoids in lettuce of aeroponics was the highest among all systems with a slight raise. The same trend was observed after 6 weeks of transplanting, that the lettuce in aeroponic produced significantly the highest content of total carotnoids compared with other systems. Aeroponic system recorded raises at total carotnoids were 25.37 and 26.86 % higher than sandy substrate and hydroponic, respectively. Also, no significant differences were recorded between lettuces in sandy substrate and hydroponic.

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