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CHICORY PRODUCTION UNDER DIFFERENT HYDROPONIC SYSTEMS USING MAGNETIZED WATER AT DIFFERENT IRRIGATION RATES

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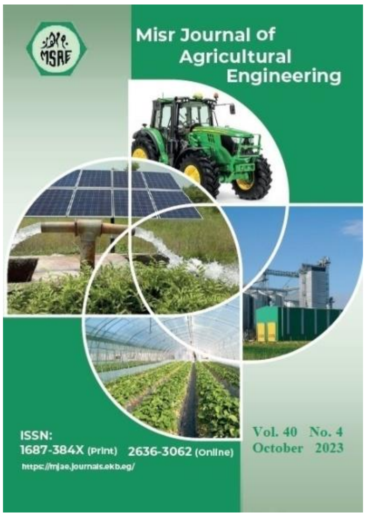

Keywords:
Hydroponic; Chicory plant; Magnetized water; Shoot; Nutrients.

ABSTRACT

This work amid to study the potential positive effects of magnetic water under different hydroponic systems to obtain max productivity and quality of water, fresh yield quantity and quality of Chicory. The effect of different nutrients sources (magnetized and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three discharges (1.0, 1.5 and 2.0 L h^{-1}) on water quality, nutrient consumption rates, fresh and dry weight of shoot and root and nutrients uptake for chicory plants were studied. The results revealed that the nutrient consumption rates by the chicory plants were higher in magnetized solution compared to those of non-magnetized solution. The highest value of the shoot height of the chicory plant (23.63 cm) was found with the magnetized solution for A shape system with 1.5 L h^{-1} discharge. The leaf area and chlorophyll of chicory were higher in magnetized solution compared to those of non-magnetized solution. Also, the leaf area and chlorophyll of chicory plants were higher in A shape system compared those of gutter system. The highest value of the fresh and dry of shoot of the chicory plant were 145.47 and 26.12 g for the magnetized solution for A shape system with 1.5 L h^{-1} discharge. The highest values of N, P, K, Ca and Mg uptake were 3.50, 0.85, 4.32, 1.96 and 0.31 %, respectively, for all treatments.

1. INTRODUCTION

Using of freshwater around the world has increasing twice as the population rate increase in the 20th century **(Frenken, 2013)**. Water deficient has a significant effect on the agricultural sector. Currently, agriculture requires 70% of freshwater worldwide and accounts for more than 90% of its consumer use **(Sato *et al.*, 2013)**. With the high population growth and changing dietary patterns worldwide, the demand for food is increasing across the globe **(Gashgari *et al.*, 2018)**. Soilless cultures such as hydroponics and aeroponics because one of the possible to the problems of safe food production, preserving, controlling the environment, and keeping suitable levels of water and fertigation use. This is the technology of the future, to supply an adequate yield that meets the demands of consumers and their quality concerns **(Putra and Yuliando, 2015)**. Soilless culture kinds currently are moved from open systems to closed systems to improve water efficiency while maintaining yield quality **(Khater *et al.*, 2021)**. Soilless systems irrigation management is very sensitive compared to soil culture this due to nutrition relays on the solution that uses it, especially when reduction of supply the water solution may cause stress, as well as leading to retarding of plant growth. Hydroponic system has many features which include higher yield production per unit area, lower moisture stress, higher water use efficiency, and greater oxygen concentration dissolved in the irrigation solution **(Khater, 2016)**.

Water treated magnetically by passing water through a magnetic field before use. The benefits of using this kind of water are still in debate in its efficiency. The mechanism of magnetization of water is proposed by **Deng and Pang (2007)** which based on molecular structure of water. The interaction of the externally used magnetic field with the electric current come from the protons (or hydrogen ions) improves conductivity through the closed hydrogen bonded chains of molecules happening in water.

The interaction of magnetic fields with flowing water was studied by **Hasaani *et al.* (2015)**. They measure absorbance, EC, TDS, pH, surface tension, viscosity and thermal conductivity for ordinary tap water before and after using magnetic fields at 6560G which were generated from suitable arrangement of permanent magnet pieces around the pipe accommodating the flowing water. They studied the physical characteristics of magnetized water were inspected with suitable and accurate measuring techniques. These include the TDS which was increased by 33%, while pH and EC are decreased by 12 and 36% respect. Also the mechanical properties such as viscosity and surface tension are decreased too by 23 and 18%, respect. In addition to the thermal conductivity was decreased by 16%.

Magnetic water treatment (MWT) techniques have shown potential as a promising technology in different fields, especially agriculture **(Ali and Samaneh, 2017)**. The utilization of the magnetized water technology is considered as a promising innovative technique to improve crop water use efficiency and yield. The application of magnetized water would insure the quantity and quality of agricultural production **(Hozayn *et al.*, 2014)**. Magnetized water can be obtained by way of passing water completely through a strong permanent magnet mounted in or on a feed conduit pipeline **(Mostafazadeh-Fard *et al.*, 2011)**. Investigation focus on the structural arrays of water would be changed when it passes through a magnetic field resulting in the increasing intercellular movement **(Scaloppi, 2008)**. Magnetic treatment modifies hydrogen bonding and increased mobility of ions in water solution and which cause in reduction in TDS, EC and increase pH of solutions **(Surendran *et al.*, 2016)**. This allows the restoration of a structure of natural and improved water in its ability to disband and tranfer minerals resulting to more nutrients absorbed in the water **(Hachicha *et al.*, 2018)**. This process cause result in higher nutrient uptake, increasing the physiological processes in crop production **(Scaloppi, 2008)**.

In the closed system of hydroponics such as nutrient film technique (NFT), nutrients are recycled to ban nutrient loss and soil pollution. Diseases and pest problems can be streaked while weeds are not found **(Pandey *et al.*, 2009)**. NFT is portion of hydroponics based on the availability of a nutrient solution for plant flow through water. In conventional methods, soil is needed but in this system the soil is not used. In NFT, factors of plant culture are streaked with facilities and requirements. This system is proper for growing plants. As well as, the productivity of crops is influenced by available facilities **(Prabhas *et al.*, 2018)**.

The effectiveness of hydroponic farming is affected by the quality of water used and the flow rate. Using magnetized water enhance the plant production under the hydroponic systems, therefore, the main aim of this study was to investigate the potential positive effects of magnetic unit with different hydroponic systems (A shape and gutter) to obtain max productivity and quality of water, fresh yield quantity and quality of Chicory.

2. MATERIALS AND METHODS

This work was conducted during the period of March to April, 2023 at the Fish Farm and Protected Houses Center, Agric. College, Moshtohor, Benha Univ., Egypt.

2.1. Materials:

2.1.1. System Description:

The experimental includes two systems, one of them used magnetized solution system and the other,non-magnetized solution system. The systems which consist of A shape units, Gutter units, magnetic device, pumps, polyethylene tanks and irrigation pipes (PVC) were fitted with each other to supply water to the system as shown in fig. (1). These systems are A shape and Gutter shape.

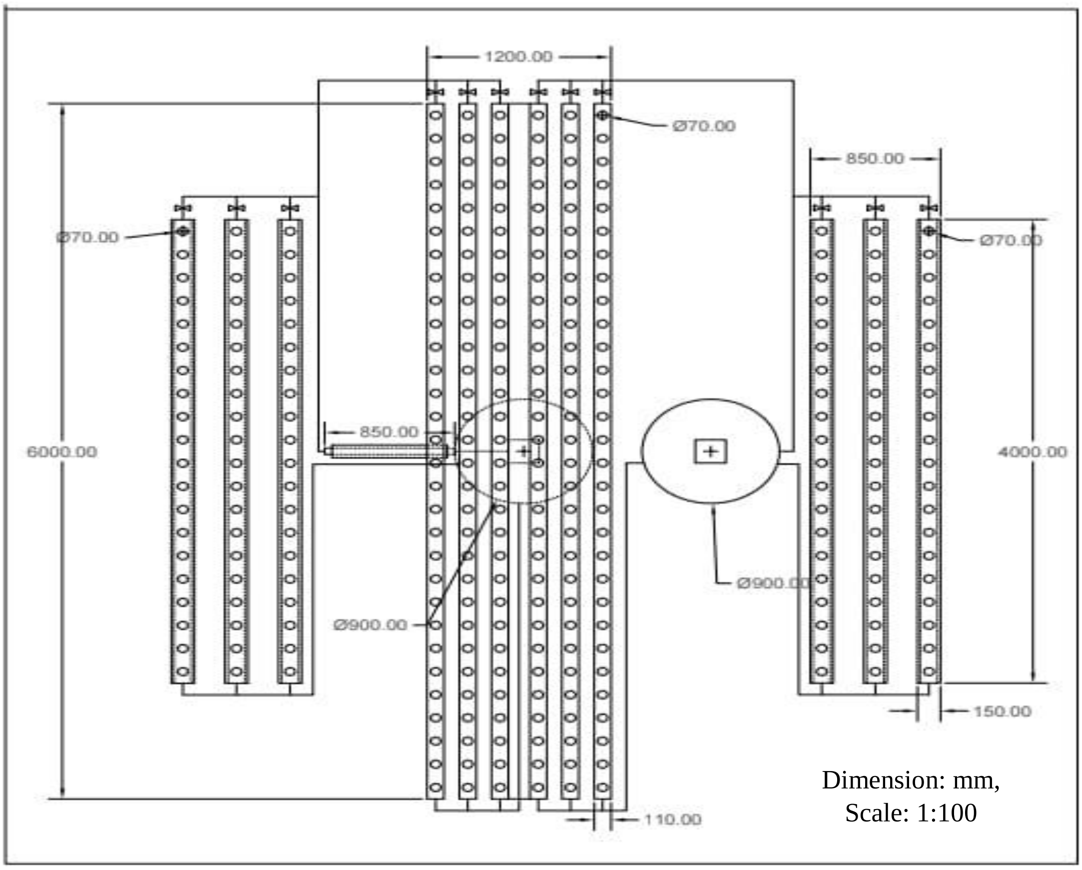

Fig. (1): Layout of the system.

2.1.1.1. A shape system:

This system has three stands made galvanized steel. Its dimensions are 1.2 m width and 1.7 m height. It uses PVC pipes with 110 mm diameter and 6.0 m long. These pipes have A shape of 2 %. Tank was provided by solution using pipes with 16 mm diameter in a closed system as shown in fig. (2).

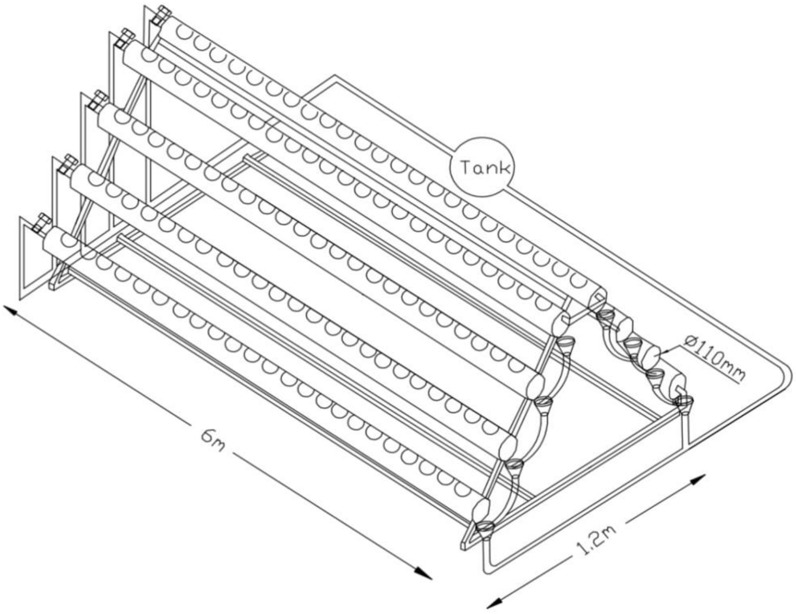

Fig. 2: A shape system.

2.1.1.2. Gutter system:

This system has three stands made galvanized steel. Its dimensions are 1.2 m width and 1.0 m height. Gutter dimension are 4.0 x 0.15x 0.10 m for length, width and height, respectively and installed with a slope of 2 %. Tank was provided by solution using pipes with 16 mm diameter in a closed system as shown in fig. (3).

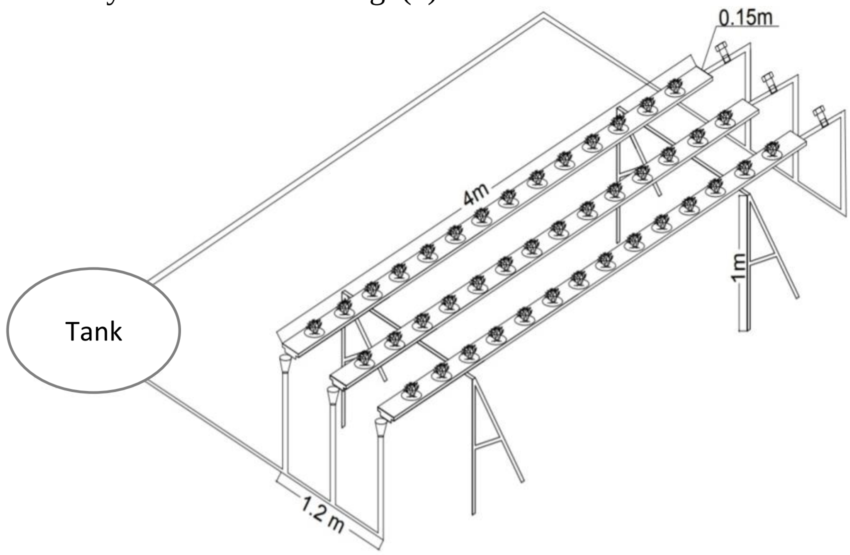

Fig. 3: Gutter system.

2.1.1.3.Magnetic device:

Water was magnetized using a magnetized field device with an intensity of 14000 Gauss. The device was part in water steam after pumping. The magnetic treatment device which was placed after the submersible pump have a magnetizer (size 1 inch, length 80 cm, output 12 m^3 h^{-1}) produced by Delta Water Company Alexandria, Egypt (Figs. 4a and b). The magnetization of nutrient solutions was applied through the all period of experiment.

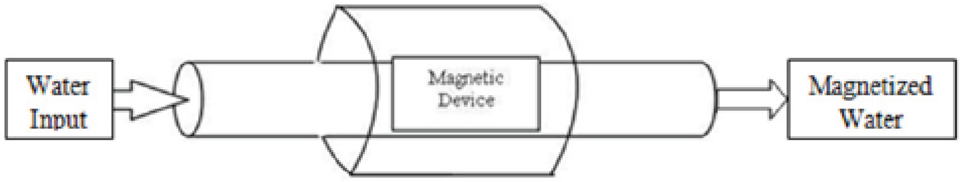

Fig. (4a): Water magnetization process.

Fig. (4b): Image of magnetic device.

2.1.1.4. Polyethylene tank:

The nutrient solutions were provided from a circular polyethylene tank, where, the drained solution is return tank to this tank for the treatments under study. The EC and pH of nutrient solution were adjusted in this tank to be 600 – 680 ppm and 6.0 – 6.5, respectively, after salt addition.

2.1.2. Chicory plants:

Chicory (*Cichorium intybus*) seedlings were put on plastic cups, irrigated using the nutrient solution. After two weeks, seedlings were moved to the hydroponic systems under study at 25 plant m^{-2} According to **Khater and Ali (2015)**.

2.2. Methods:

2.2.1. Treatments:

These experimental treatments were carried out under two systems of hydroponics using both magnetized and non-magnetized water at 3 flow rates. The total treatments: 2 x 2 x 3 flow rates = 12 treatments.

2.2.2. Measurements:

2.2.2.1. Water properties:

Water samples were taken from both influent and effluent of the hydroponic system to measured EC, pH, water temperature, nitrogen, Phosphorus, Potassium, Calcium and Magnesium each seven days. pH meter (Model ORION 105 –Range 0.0 – 9999.9 ppm ± 0.5 ppm, USA) was used to measured water pH Water pH measured by pH Meter. EC Meter (Model ORION 230A –Range 0.0 – 19.99 ± 0.05, USA) was used to measured water temperature and EC. Kjeldahl digestion apparatus was used to measured nitrogen **(Bremmer and Mulvaney, 1982)**. Photofatometer (Model Jenway PFP7 – Range 0 - 160 mmol L^{-1}, USA) was used to measured potassium, calcium and magnesium and colorimetrically following the **Murphy and Riley (1962)** method was used to measured phosphorus.

The consumption rate of nutrient was estimated by measuring the differences in the flow rate at inlet and outlet of the nutrients supply using the following formula **(Khater *et al.*, 2015)**:

$$NCR = \frac{NC_{in} - NC_{out}}{\mathrm{n}} \times Q \times 24 \quad (1)$$

where:

NCR is the consumption rate of nutrient, mg day^{-1} plant^{-1}

Nc_{in} is the nutrients at inlet of the hydroponic unit, mg L^{-1}

Nc_{out} is the nutrients at outlet of the hydroponic unit, mg L^{-1}

Q is the discharge, L h^{-1}

n is the number of plants

2.2.2.2. Plant samples:

Plant samples were taken to measure the root length and mass under different treatments of study. 3 plants of each treatment were taken every week Root length was measured weekly. Three chicory plants samples were taken to measure shoot length, leaf area, chlorophyll and shoot and root dry weight. Shoot length of chicory plant was measured by using a digital caliper (Model TESA 1p65- Range 0-150 mm ± 0.01 mm, Swiss). A planimeter (Model Placom KP -90 N- Range 0-10 m2 ± 0.2 %, Japan) was used to measure the leaf area of the chicory plants. By the end of experiment, shoot and root fresh and dry weight of chicory were determined using an oven drying method at 65 ºC until at reach constant weight.

Macro elements were determined according to **Chapman and Partt (1961).** Nitrogen was measured according to **Bremmer and Mulvaney (1982)**. Potassium, Photofatometer (Model Jenway PFP7 – Range 0 - 160 mmol L^{-1}, USA) was used to determined calcium and magnesium and phosphorus was measured colorimetrically following the **Murphy and Riley (1962)** method.

3. RESULTS AND DISCUSSION

3.1. Water properties:

Water properties as affected by magnetization process compared to non-magnetized water under two systems of hydroponics (A shape and gutter) at three flow rates (1.0, 1.5 and 2.0 L h^{-1} per plant) as shown in table (1). The results revealed that the water temperature did not show any variation throughout the experimental period for the values of all treatments, it ranged from 27.92 ± 0.2 to 28.01 ± 0.3 ºC. EC of water ranged from 649.3 ± 8.5 to 681.3 ± 10.7 ppm. The water pH ranged from 5.5 ± 0.1 to 6.3 ± 0.4, with no marked variation among the treatments at time of taken samples. The highest value of nitrogen (N) concentration was 178.29 ± 4.71 ppm for A shape system at 1.0 L h^{-1} flow rate for magnetized water, while, the lowest value of nitrogen (N) concentration was 149.06 ± 4.91 ppm with found of gutter system at 1.5 L h^{-1} flow rate for non-magnetized water. The phosphorus concentration values were ranged from 23.00 ± 2.76 to 27.66 ± 2.91 ppm for all treatments. K, Ca and Mg concentrations ranged from 163.39 ± 8.46 to 197.21 ± 9.32, 57.63 ± 6.80 to 69.56 ± 7.04 and 37.60 ± 4.71 to 46.32 ± 4.59 ppm, respectively, for all treatments. The obtained results are agreement with the results of **Amin *et al.* (2022)**.

Table (1): Some water quality parameters

Parameter	Discharge, L h^{-1}	Magnetized Solution		Non-Magnetized Solution	
		A Shape	Gutter	A Shape	Gutter
EC, ppm	1.0	671.1±8.2	658.6±7.7	676.6±6.9	650.5±7.5
	1.5	681.3±10.7	674.9±7.1	670.0±8.0	670.8±5.9
	2.0	677.7±7.2	670.1±9.0	649.3±8.5	665.7±6.6
pH	1.0	5.9±0.3	5.6±0.3	6.1±0.5	6.1±0.6
	1.5	5.8±0.2	5.5±0.2	6.o±0.4	5.9±0.5
	2.0	5.8±0.1	5.5±0.1	6.3±0.4	6.0±0.5
N, ppm	1.0	178.29±4.71	165.53±4.89	163.71±4.27	151.33±5.60
	1.5	175.99±3.86	164.07±4.52	162.22±2.98	149.06±4.91
	2.0	171.58±3.78	162.26±4.03	158.59±4.01	150.47±4.67
P, ppm	1.0	27.05±2.34	25.22±3.04	24.78±2.99	23.36±2.70
	1.5	27.66±2.91	25.06±2.79	24.62±2.78	23.27±2.66
	2.0	27.31±2.39	25.79±2.81	24.71±3.39	23.00±2.76
K, ppm	1.0	196.55±6.90	181.64±8.92	179.67±7.81	164.81±8.77
	1.5	197.21±9.32	182.34±9.40	181.62±6.96	169.39±9.04
	2.0	189.80±8.71	179.99±8.22	179.01±7.95	163.87±8.46
Ca, ppm	1.0	67.31±5.69	62.70±7.38	61.33±5.91	58.54±6.09
	1.5	69.56±7.04	63.46±7.04	63.28±8.73	61.57±7.72
	2.0	66.32±8.21	60.92±8.17	59.65±7.64	57.63±6.80
Mg, ppm	1.0	44.05±5.03	41.38±5.97	39.32±6.91	37.89±4.43
	1.5	46.32±4.59	43.71±3.99	40.07±5.22	39.01±4.68
	2.0	43.71±4.88	40.30±4.50	38.27±6.06	37.60±4.71

3.2. Nutrients consumption rate:

Table (2) shows the nutrients consumption rate by chicory during the growth period in different source of nutrients (magnetized water and non-magnetized water), two systems of hydroponics (A shape and gutter systems) and three discharges (1.0, 1.5 and 2.0 L h^{-1} per plant). The nutrients consumption rate by the chicory were higher for magnetized solution compared to those of non-magnetized solution, also the nutrients consumption rate by the chicory plants were higher for A shape system compared to the other system. The nitrogen (N) consumption rate values were 825.26, 893.08 and 760.01 and 633.14, 729.71 and 558.85 mg $plant^{-1}$ at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respect, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the consumption rate of nitrogen value was 782.87, 859.73 and 665.66 and 628.74, 705. 32 and 535.20 mg $plant^{-1}$ at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respectively, for both A shape and gutter hydroponic systems.

The consumption rates of phosphorus were 669.29, 822.74 and 593.07 and 533.40, 748.23 and 495.27 mg $plant^{-1}$ at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respectively, for A shape and gutter systems with magnetized solution during experimental period. Meanwhile, they were 592.68, 761.96 and 527.05 and 581.98, 700.10 and 450.11 mg $plant^{-1}$ at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respectively, for A shape and gutter systems for non-magnetized solution. The potassium (K) consumption rate was ranged from 1387.21 to 2271.02 mg plant^{-1} for all treatments. The highest value of calcium (Ca) and magnesium (Mg) consumption rate by chicory plants were 429.30 and 613.57 mg plant^{-1} were found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate. These results agreed with those obtained by **Khater (2006), Genuncio *et al.* (2012) and Amin *et al.* (2022)** whose found that the highest values of nutrients consumption rate of plant were found with a flow rate of 1.5 L h^{-1} plant^{-1}.

Table (2): The nutrients consumption rate of chicory plants grown in different treatments.

Parameter	Discharge, L h^{-1}	Magnetized Solution		Non-Magnetized Solution	
		A Shape	Gutter	A Shape	Gutter
		Consumption Rate of Nutrients, mg plant^{-1}			
N	1.0	825.26	633.14	782.87	628.74
	1.5	893.08	729.71	859.73	705.32
	2.0	760.01	558.85	665.66	535.20
P	1.0	669.29	533.40	592.68	581.98
	1.5	822.74	748.23	761.96	700.10
	2.0	593.07	495.27	527.05	450.11
K	1.0	2069.90	1660.50	1930.57	1477.36
	1.5	2271.02	1798.04	2108.82	1593.18
	2.0	1886.61	1583.10	1823.80	1387.21
Ca	1.0	375.83	342.84	376.13	319.19
	1.5	429.30	399.25	432.48	359.19
	2.0	321.53	289.16	311.04	301.54
Mg	1.0	541.86	473.68	512.78	458.55
	1.5	613.57	530.91	584.88	507.12
	2.0	473.97	405.19	456.98	410.10

3.3. Chicory growth parameters:

3.3.1. Shoot length:

Figs. (5a and b) show the shoot length of chicory plants grown in different source of nutrients (magnetized and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three flow rates (1.0, 1.5 and 2.0 L h^{-1} per plant). The shoot length of chicory plants were taller in magnetized solution compared to those of non-magnetized solution, also the shoot height of chicory plants were taller in A shape system compared those of gutter system. It also indicated that, the shoot length of the chicory plant grown in different cultures increases with increasing plant age. The shoot height of chicory plants increased from 11.17 to 19.10, 10.33 to 23.63 and 11.0 to 19.63 and 10.27 to 14.70, 9.83 to 17.03 and 9.50 to 14.57 cm after 6 weeks, respectively, at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1} in magnetized and non-magnetized solution, respect, for A shape system.

For gutter hydroponic system, the shoot length of the chicory plants grown in different culture system increases with increasing plant age. The shoot height of chicory plants increased from 10.07 to 16.27, 10.17 to 19.67 and 8.30 to 15.90 and 10.37 to 12.53, 10.27 to 14.07 and 10.53 to 13.50 cm after 6 weeks, respect, at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1} in magnetized solution and non-magnetized solution, respectively. The highest value of the shoot height of the chicory plant was 23.63 cm was found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate.

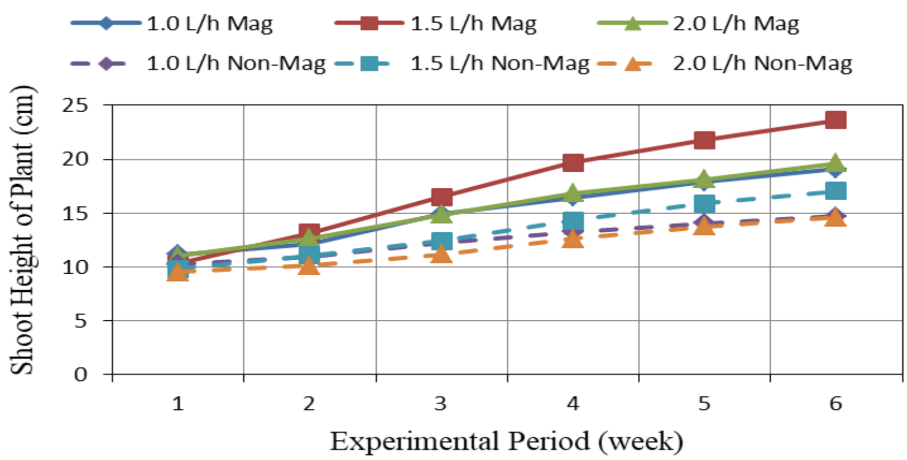

Fig. (5a): The shoot length of the chicory plants grown in A shape hydroponic system.

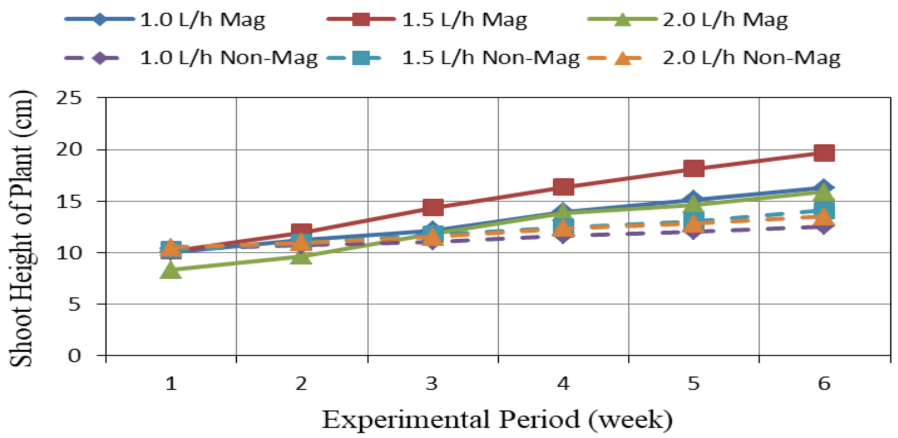

Fig. (5b): The shoot length of the chicory plants grown in gutter hydroponic system.

3.3.2. Leaf area:

Figs. (6a and b) show the leaf area of chicory grown during in different source of nutrients (magnetized and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three flow rates (1.0, 1.5 and 2.0 L h^{-1} per plant). The leaf area of chicory plants were higher in magnetized solution compared to those of non-magnetized solution, also the leaf area of chicory plants were higher in A shape system compared those of gutter system. The results also indicate that the leaf area of the chicory plant increases with increasing plant age. It could be seen that the leaf area of chicory plants increased from 25.88 to 85.30, 31.64 to 123.51 and 26.47 to 90.91 and 20.43 to 60.06, 23.56 to 81.30 and 18.62 to 66.93 cm^2 after 6 weeks, respectively, at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$ in magnetized and non-magnetized solution, respect, for A shape hydroponic system.

For gutter hydroponic system, the leaf area of the chicory increases with increasing plant age. It increased from 20.46 to 64.79, 24.00 to 95.10 and 18.08 to 65.19 and 16.20 to 41.30, 21.86 to 56.73 and 23.72 to 50.22 cm^2 after 6 weeks, respectively, at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$ in magnetized solution and non-magnetized solution, respectively. The highest value of the leaf area of the chicory plant was 123.51 cm^2 was found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate.

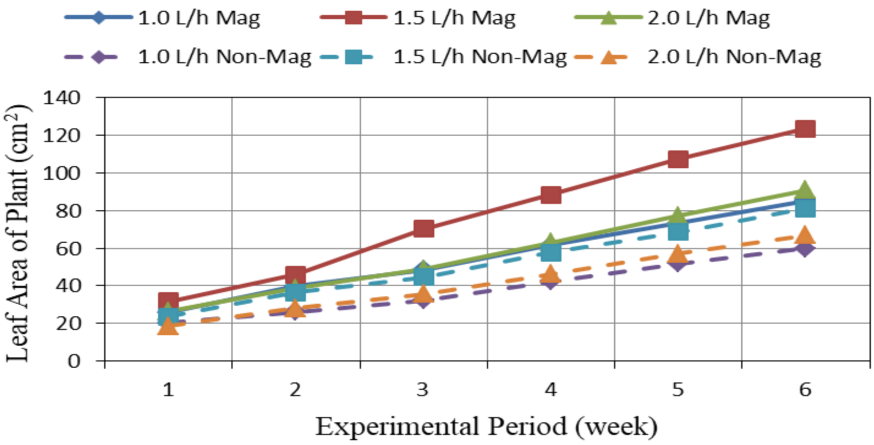

Fig. (6a): The leaf area of the chicory grown in A shape system.

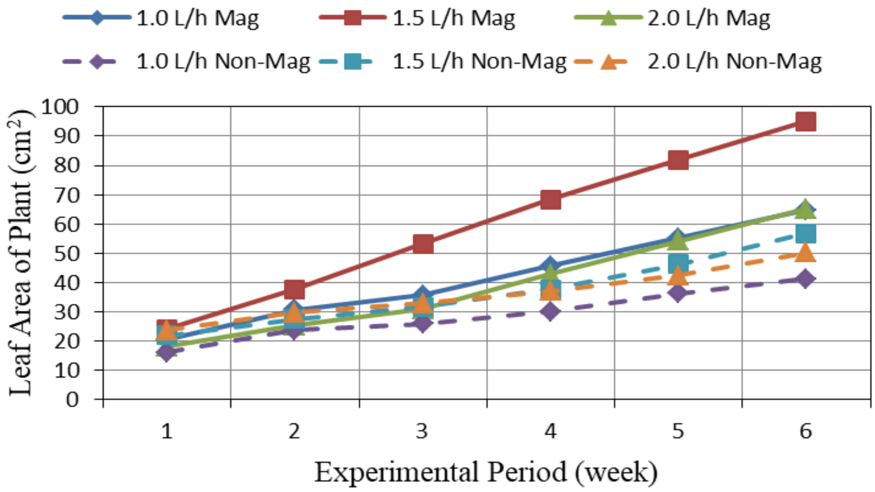

Fig. (6b): The leaf area of the chicory grown in gutter system.

3.3.3. Chlorophyll:

Figs. (7a and b) show the chlorophyll of chicory plants grown in different source of nutrients (magnetized and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three flow rates (1.0, 1.5 and 2.0 L h^{-1} per plant). The chlorophyll of chicory were higher in magnetized solution compared to non-magnetized solution, also the chlorophyll of chicory plants were higher in A shape system compared those of gutter system. The chlorophyll of the chicory increased with increasing plant age, where, it increased from 50.50 to 101.37, 58.07 to 123.00 and 53.53 to 106.80 and 44.37 to 80.07, 47.33 to 84.73 and 46.50 to 80.63, respect, after 6 weeks at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$ in magnetized and non-magnetized solution, respectively, for A shape system.

For gutter hydroponic system, the chlorophyll of the chicory plants grown in different culture system increases with increasing plant age. It increased from 53.00 to 85.30, 55.67 to 107.70 and 53.70 to 94.47 and 39.60 to 56.73, 49.13 to 69.20 and 40.60 to 67.37, after 6 weeks, respect, at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$ in magnetized solution and non-magnetized solution, respectively. The highest value of the chlorophyll of the chicory plant (123.00) was found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate.

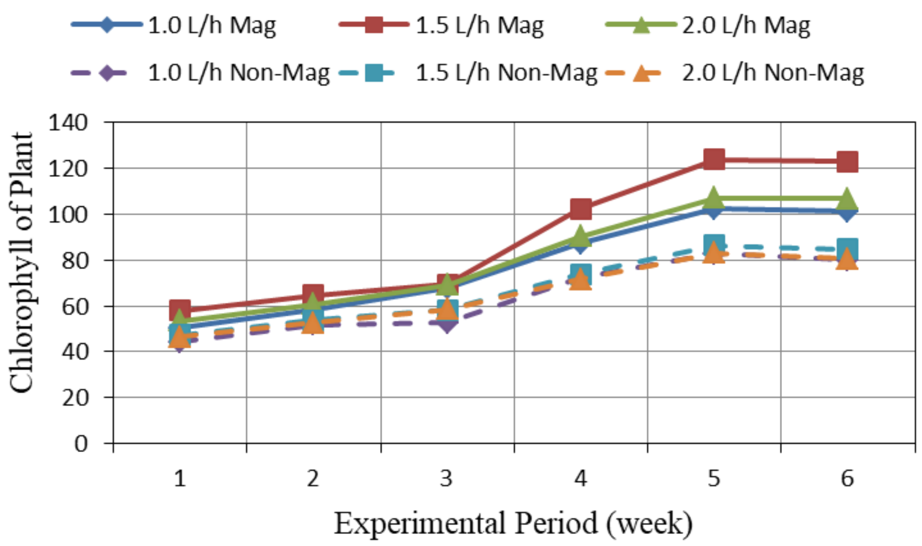

Fig. (7a): The chlorophyll of the chicory plants grown in A shape system.

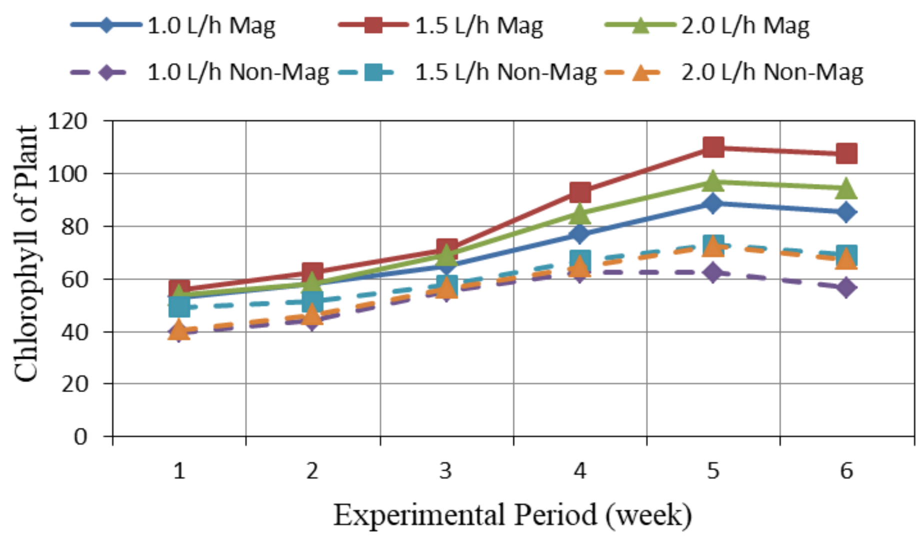

Fig. (7b): The chlorophyll of the chicory plants grown in gutter system.

3.4. Fresh and dry weight of shoot and root:

3.4.1. Fresh and dry weight of shoot:

Figs. (8a and b) show fresh and dry weight of shoot of chicory plants grown in different sources of nutrients (magnetized solution and non-magnetized solution), two systems of hydroponics (A shape and gutter hydroponics systems) and three discharges (1.0, 1.5 and 2.0 L h^{-1} per plant) at the end of experimental period. The fresh and dry weight of shoot plants were higher in magnetized solution compared to those of non-magnetized solution, also the fresh and dry weight of shoot plants were higher in A shape system compared those of gutter system. The fresh weight of shoot of chicory was 114.81, 145.47 and 128.82 and 86.66, 135.37 and 118.99 g $plant^{-1}$ at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respectively, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the fresh weight of shoot of chicory plants values were 109.85, 121.18 and 118.99 and 56.65, 120.10 and 70.82 g $plant^{-1}$ for 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respectively, for A shape and gutter systems. This is attributed to the effect of different nutrient solution in the yield, because the optimum growth depends on the amount of nutrient available for the plant. These results agreed with those obtained by **Khater (2006), Maucieri *et al.* (2019) and Khater *et al.* (2021)**.

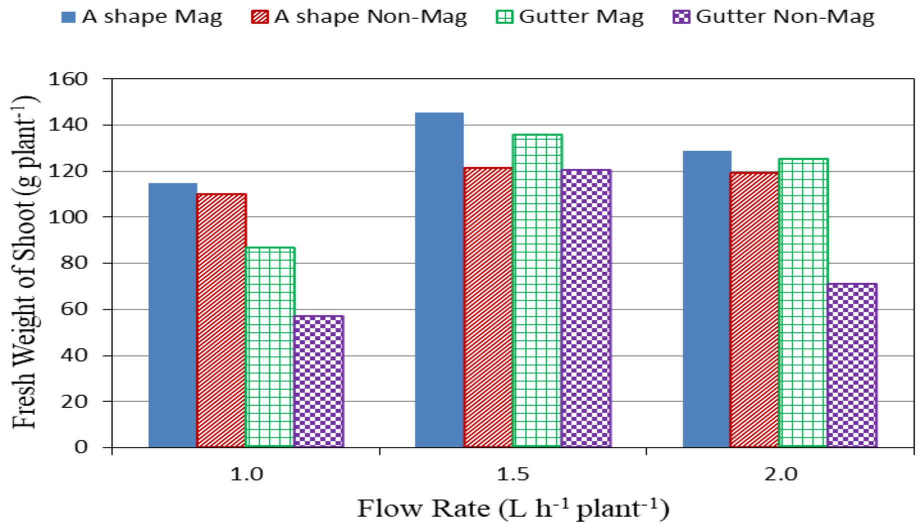

Fig. (8a): The fresh weight of shoot of chicory plants.

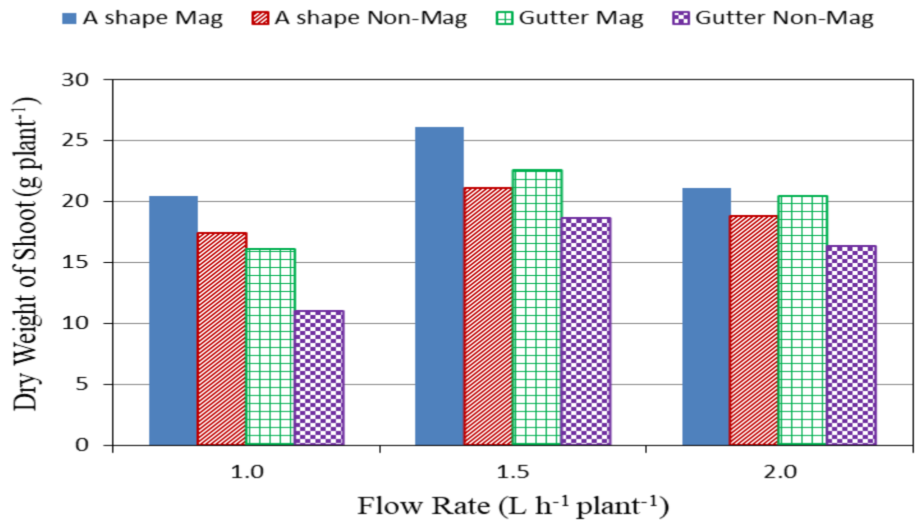

Fig. (8b): The dry weight of shoot of chicory plants.

The dry weight of shoot of chicory plants values were 20.44, 26.12 and 21.08 and 16.09, 22.58 and 20.42 g plant^{-1} at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1}, respect, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the dry weight of shoot of chicory plants values were 17.34, 21.06 and 18.73 and 11.00, 18.63 and 16.27 g plant^{-1} at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1}, respect, for A shape and gutter systems. The highest values of fresh and dry weight of shoot (145.47 and 26.12 g plant^{-1}) were found with A shape hydroponic system and 1.5 L h^{-1} plant^{-1} of flow rate with magnetized solution, while, the lowest values of fresh and dry weight of shoot (56.65 and 11.00 g plant^{-1}) were found with gutter hydroponic system and 1.0 L h^{-1} plant^{-1} of flow rate with non-magnetized.

These results agreed with those obtained by **Genuncio *et al.* (2012), Hussain *et al.* (2014) and Khater *et al.* (2015)** whose found that the highest values of fresh and dry weight of plant were found with a flow rate of 1.5 L h^{-1} $plant^{-1}$.

3.4.2. Fresh and dry weight of root:

Figs. (9a and b) show fresh and dry weight of root of chicory plants grown in different sources of nutrients (magnetized and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three discharges (1.0, 1.5 and 2.0 L h^{-1} per plant) at the end of experimental period. The fresh and dry weight of root plants were higher in magnetized solution compared to other system, also the fresh and dry weight of root plants were higher in A shape system compared those of gutter system. The results indicate that the fresh weight of root of chicory plants values were 45.34, 80.91 and 72.58 and 24.10, 60.62 and 45.33 g $plant^{-1}$ at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respect, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the fresh weight of root of chicory plants values were 22.92, 48.77 and 30.53 and 20.07, 40.11 and 22.53 g $plant^{-1}$ for 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respect, for A shape and gutter systems.

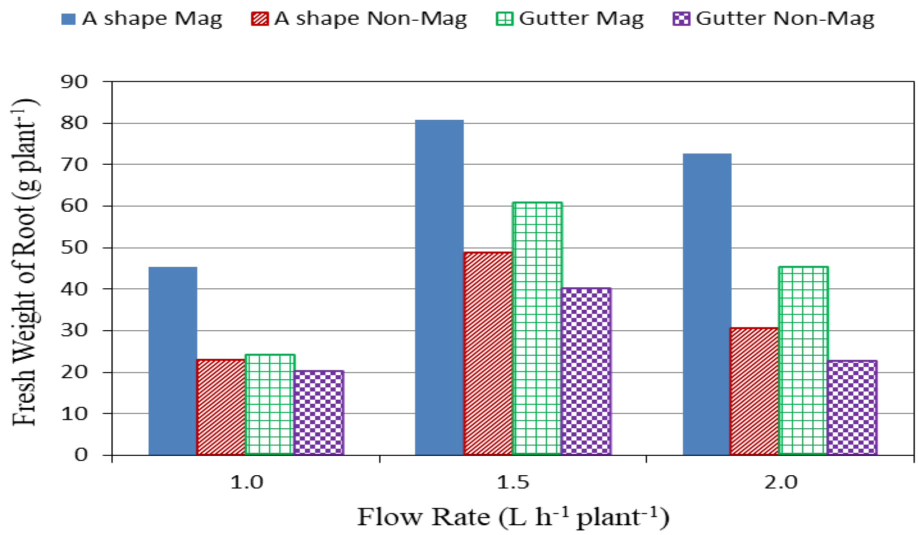

Fig. (9a): Fresh weight of root of chicory.

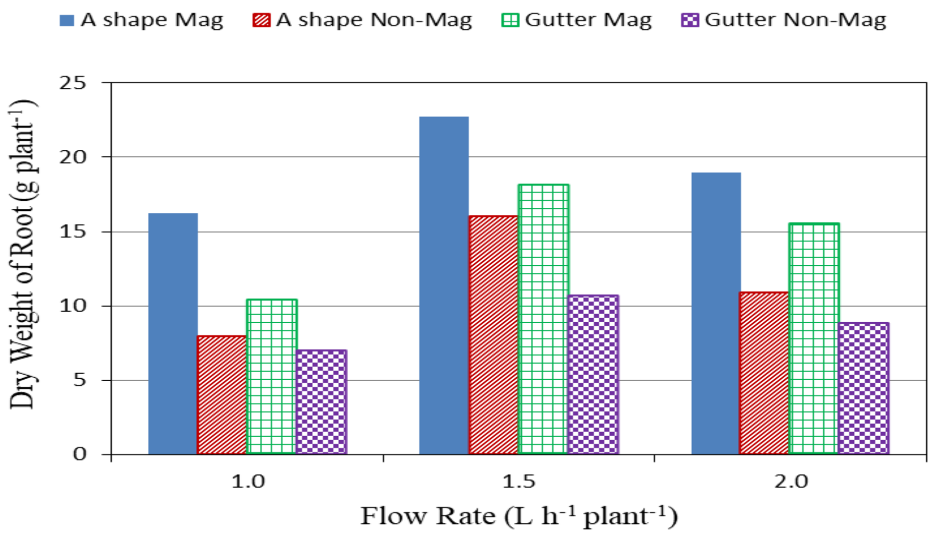

Fig. (9b): Dry weight of root of chicory.

The dry weight of root of chicory plants was 16.22, 22.74 and 18.95 and 10.36, 18.09 and 15.48 g plant^{-1} at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1}, respect, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the dry weight of root of chicory plants values were 6.99, 16.01 and 10.86 and 7.90, 10.67 and 8.82 g plant^{-1} at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1}, respectively, for A shape and gutter systems. The highest values of fresh and dry weight of root (80.91 and 22.74 g plant^{-1}) were obtained with A shape hydroponic system and 1.5 L h^{-1} plant^{-1} of discharge with magnetized solution, while, the lowest values of fresh and dry weight of root (16.01 and 6.99 g plant^{-1}) were obtained with gutter hydroponic system and 1.0 L h^{-1} plant^{-1} of discharge with non-magnetized. These results agreed with those obtained by **Amin *et al.* (2022)** whose found that the highest values of fresh and dry weight of root were found with a flow rate of 1.5 L h^{-1} plant^{-1}.

3.5. Nutrients uptake:

Table (3) shows the nutrients uptake by chicory plants in different sources of nutrients (magnetized and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three discharges (1.0, 1.5 and 2.0 L h^{-1} per plant). The nutrients uptake by the chicory plants were higher in magnetized solution compared to non-magnetized solution, also the nutrients uptake by the chicory plants were higher in A shape system compared to those of gutter system. The nitrogen (N) uptake by chicory plants were 3.22, 3.50 and 3.08 and 3.02, 3,35 and 3.01 % at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1}, respectively, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the N uptake by chicory plants values were 2.97, 3.11 and 2.95 and 2.88, 2.90 and 2.79 % at 1.0, 1.5 and 2.0 L h^{-1} plant^{-1}, respect, for A shape and gutter systems.

Table (3): The nutrients uptake of chicory plants grown in different treatments under study.

Parameter	Discharge, L h^{-1}	Magnetized Solution		Non-Magnetized Solution	
		A Shape	Gutter	A Shape	Gutter
		Nutrients Uptake, %			
N	1.0	3.22	3.02	2.97	2.88
	1.5	3.50	3.35	3.11	2.90
	2.0	3.08	3.01	2.95	2.79
P	1.0	0.46	0.38	0.36	0.35
	1.5	0.85	0.63	0.42	0.38
	2.0	0.80	0.47	0.40	0.37
K	1.0	3.83	3.75	3.49	2.92
	1.5	4.32	3.90	3.57	3.21
	2.0	3.91	3.61	3.33	2.89
Ca	1.0	1.81	1.72	1.40	1.32
	1.5	1.96	1.81	1.76	1.72
	2.0	1.83	1.73	1.39	1.32
Mg	1.0	0.22	0.19	0.21	0.17
	1.5	0.31	0.27	0.28	0.23
	2.0	0.24	0.18	0.22	0.20

The phosphorus uptake by chicory was 0.46, 0.85 and 0.80 and 0.38, 0.63 and 0.47 % at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respect, for A shape and gutter systems with magnetized solution during experimental period. For non-magnetized solution, the P uptake by chicory plants values were 0.36, 0.42 and 0.40 and 0.35, 0.38 and 0.37 % at 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$, respect, for A shape and gutter systems. The potassium (K) uptake was ranged from 2.89 to 4.32 % for all treatments. The highest value of Ca and Mg uptake by chicory plants were 1.96 and 0.31 % were found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate.

4. CONCLUSION

The experiment was carried out to investigate the potential positive effects of magnetic unit with different hydroponic systems to try to reach the maximum possible productivity and quality of water, fresh yield quantity and quality of Chicory. To achieve that, the effect of different nutrients sources (magnetized solution and non-magnetized solution), two systems of hydroponics (A shape and gutter systems) and three flow rates (1.0, 1.5 and 2.0 L h^{-1}) on water quality were study. Nutrients consumption rate, fresh and dry weight of shoot and root and nutrients uptake for chicory plants were also study. The obtained results can be summarized as follows:

- The N, P, K, Ca and Mg consumption rate by chicory plants ranged from 894.08 to 535.20, 822.74 to 450.11, 2271.02 to 1387.21, 429.30 to 301.54 and 613.53 to 410.10 mg $plant^{-1}$ for all treatments under study.
- The highest value of the shoot height of the chicory plant was 23.63 cm was found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate.
- The highest value of the fresh and dry of shoot of the chicory plant were 145.47 and 26.12 g was found with the magnetized solution for A shape system with 1.5 L h^{-1} flow rate.
- The highest values of N, P, K, Ca and Mg uptake were 3.50, 0.85, 4.32, 1.96 and 0.31 %, respectively, for all treatments.

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انتاج الشيكوريا تحت نظم زراعة مائية مختلفة باستخدام المياه الممغنطة بمعدلات رى مختلفة

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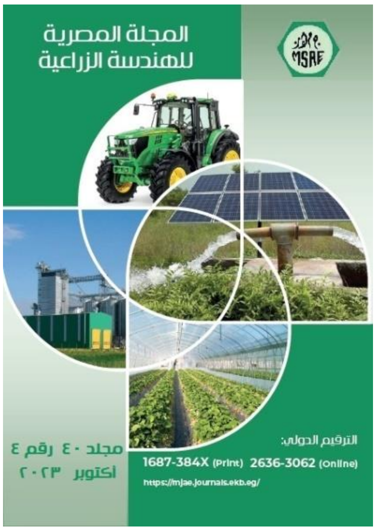

الكلمات المفتاحية:
الزراعة المائية؛ نبات الشيكوريا؛ الماء الممغنط؛ المجموع الخضرى؛ المغذيات.

الملخص العربى

يهدف هذا البحث الى دراسة استخدام الوحدات الممغنطة بأنظمة الزراعة المائية المختلفة لمحاولة الوصول إلى أقصى قيمة ممكن من الإنتاجية وجودة المياه، وكمية وجودة المحصول الناتج من نبات الشيكوريا. ولتحقيق ذلك تم دراسة تأثير كلا من المحلول الممغنط والمحلول غير الممغنط ونظامين من الزراعة المائية وهما نظام الزراعة على شكل حرف A ونظام الزراعة فى المجارى (Gutter) وثلاثة تصرفات للمياه وهى ١,٠ و١,٥ و٢,٠ لتر ساعة$^{-1}$ لكل نبات على جودة المياه معدل استهلاك المغذيات والوزن الطازج والجاف للمجموع الخضرى والجذرى لنبات الشيكوريا. وكان اهم النتائج هى: كان اعلى معدل استهلاك المغذيات لنباتات الشيكوريا باستخدام المحلول المغذى الممغنط اعلى من النباتات النامية فى المحلول المغذى الغير ممغنط. كانت اعلى قيمة لارتفاع المجموع الخضرى هى ٢٣,٦٣ سم للنباتات النامية فى المحلول المغذى الممغنط فى نظام الزراعة المائية على شكل حرف A ومعدل تصرف ١,٥ لتر ساعة$^{-1}$. كانت اعلى قيمة لكل من مساحة سطح الورقة والكلوروفيل لنباتات الشيكوريا باستخدام المحلول المغذى الممغنط اعلى من النباتات النامية فى المحلول المغذى الغير ممغنط. وايضا كانت اعلى قيمة لكل من مساحة سطح الورقة والكلوروفيل لنباتات الشيكوريا النامية فى نظام الزراعة على شكل حرف A ومعدل تصرف ١,٥ لتر ساعة$^{-1}$ اعلى من النباتات النامية فى المحلول المغذى الغير ممغنط. كانت اعلى قيمة لكل من الوزن الطارج والجاف للمجموع الخضرى لنبات الشيكوريا هى ١٤٥,٤٧ و٢٦,١٢ جم للنباتات النامية فى المحلول المغذى الممغنط فى نظام الزراعة المائية على شكل حرف A ومعدل تصرف ١,٥ لترساعة$^{-1}$. كانت اعلى قيمة لمعدل امتصاص النيتروجين والفوسفور والبوتاسيوم والكالسيوم والماغنسيوم للنباتات هى ٣,٥٠ و٠,٨٥ و٤,٣٢ و١,٩٦ و٠,٣١ % على الترتيب لكل المعاملات.