Egypt. J. Chem. **Vol. 67,** No. 8 pp. 635 - 646 (2024)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Salinity Stress Implication on Vegetation, Anatomy and Yield of Some (*Chenopodium quinoa* Willd.) Varieties using Magnetized Water Technology

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Abstract

In Sinai region (one of the coastal areas of the Red Sea), Egypt, the agriculture sector relies primarily on the well water of diverse grades of salinity that may prohibit sowed crops from attaining full productivity. Additionally, the illogical use of well water is implemented in lowering both level and quality of irrigation water via increased salinization. To alleviate salinity stress in either irrigation water and/or soil, agricultural scientists under these conditions and the similar coastal areas of the Red Sea use common (i.e., salt-tolerant or moderate crops such as quinoa) and/or un-common methods (i.e., magnetic technology, etc.). A split-plot field trial using four Quinoa (*Chenopodiumquinoa*Willd.) cultivars (Q1, Chibayi, Q37 and KVL)and three irrigation water treatments [i) Brackish-water (BW), ii) Magnetic-BW_1; brackish water following magnetization via passing 3 inches static-magnetic; 3.75 mT; manufactured by Delta Water Company, Industrial Zone-1, Alexandria, Egypt; and lastly, iii) Magnetic-BW_2; brackish water following magnetization via passing a three-inch static magnetic unit; 0.75 mT; manufactured by Magnetic-Technologies Company, Dubai, UAE]. The experiment was performed at Agricultural Experimental Station of Desert Research Centre, Ras Sidr District, South Sinai Governorate, Egypt through the winter seasons of 2019/20 and 2020/21. Data demonstrated that irrigation of the four Quinoa cultivars plots with either Magnetic-BW_1 orMagnetic-BW_2)considerably overrode irrigation with ordinary BW in vegetation growth, dry matter accumulation of plant organs, total chlorophyll, anatomical characteristics of stem and leaves, concentration of some macro (N, K, Mg, Ca) and micro-elements (Fe, Mn)in dry leaves at 85 days after sowing, yield components and yield (Kg fed^{-1}; fed=4200 m^2) of quinoa plant. The percent of improvement ranged between 7.82-36.55%, 24.74-32.77%, 21.22, 12.77-73.15%, 5.21-87.50%, 16.80-30.20%, 14.24-64.07%, 2.22-27.73 and 18.28% the parameters mentioned above respectively (Average of both magnetically treated BW). Revers trends were recorded in concentration of sodium zinc and copper were reduced by 74.39, 22.59 and 43.33%, respectively. The results also showed that the four cultivars differed significantly for the previous characters where Chibayi, came in the first order, followed by Q37 and KVL and Q1, respectively. Generally, all cultivars showed positive and significant responses under both magnetically treated brackish water treatments (Magnetic-BW_1 orMagnetic-BW_2)compared to BW. In conclusion, the result obtained clarifies that the application of magnetized water technology can be applied as a substantial way of minimizing salinity stress and getting quinoa yield better

***Keywords*:** Quinoa , Growth, Anatomy, Yield, Magnetically brackish-water, Salinity stress

1. Introduction

In Sinai region, Egypt, the agriculture sector relies at most on the well water of different levels of salinity that may hinder planted crops from achieving their whole output. In addition, the over-use of well water, results in reduction of level and quality of irrigation water through raised salinization. To alleviate salinity stress either in irrigation water and/or in soil, agricultural scientists

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Receive Date: 09 April 2024, Revise Date: 22 May 2024, Accept Date: 27 May 2024
DOI: 10.21608/EJCHEM.2024.282411.9580

under these conditions use common (i.e., salt-tolerant or moderate crops such as quinoa) and/or un-common methods (i.e., magnetized water technology, etc..).

As un-traditional methods, novel physical techniques depend on the implementation of magnetic fields comprising irrigation with magnetically handled water and/or seeds being used in agriculture. The utilization of magnetic technology in agriculture is considered one of non-classical technologies reported by many works in different countries. It is economic, and safe for health as well as the environment. Also, this technology is promising to ameliorate productivity of various crops and efficiency of water use under normal and/or salinity stress conditions. Application of magnetized water to salty soil results in breaking down of the salt crystals twice as fast as un-magnetized water permitting the salt to be filtrated from the soil **[1&2]**.

The multi-polar magnetization leads to alteration of physiochemical features of natural water leading to improvement of its leaching and dissolving capacity. Magnetic treatments of water sweeps salts out of the soil, 3-4 times more than non-treated water and in the same time oxygen concentration in such water elevates by 10% **[3]**. After magnetic washing of the soil, the content of nourishing ingredients measurably elevates. It is possible to irrigate using water that would formerly have comprised up to 410 g/l of salt. Moreover, magnetized systems for water and/or seeds were reported to play a great role in improving germination, growth and productivity of many crops and water use efficiency under normal and salinity stress conditions **[2,3,4,5,6,7,8,9,10,11,12,13]**.

In the 21st century, food security is considered a global concern; planting field crops beneath harsh conditions of draught environment in sandy soil with using irrigation water of high salinity is one of the greatest threats confronting food security particularly for small-scale farmers. A few years ago, the food and agriculture organization (FAO) selected quinoa as one of the crops directed to present the solution **[14].**

Quinoa (*ChenopodiumquinoaW*illd.) is attracting attention by agricultural scientists as subsidiary grain crop for human and animal food stuff due to nutritional value, essential amino acids and high-protein content (Bhargava *et al*., 2003), a wide extent of minerals (Ca, Cu, Fe, Mg, Zn) and vitamins (A, B2, E) [**15**]. “Quinoa” is a food crop that newly introduced to fill up part of food gap, since; it is dryness and salinity tolerant so giving a potent growth prospect under the extreme ruthless conditions of aridity and soil salinity. Quinoa can raise in sandy soil of arid and semiarid areas and with other most harsh abiotic counter factors that influence crop yield.

This study targeted to scout the role of the application of magnetically addressed brackish-water treatments for optimization of growth and productivity of some quinoa varieties under Sinai regions. By determination of growth rate, anatomical features of stem and leaf, nutrient-elements in soil and plants, yield and yield components of tested four quinoa varieties, conclusions can be designed a hopeful plan of saline water irrigation for the crop cultivation.

2. Materials and Methods

A field trial using four Quinoa (*Chenopodiumquinoa*) varieties (Q1, Chibayi, Q37 and KVL)under three irrigation water addresses [i) Brackish-water (BW), ii) Magnetic-BW_1; brackish water following magnetization via passing a three inches static-magnetic; 3.75 mT; manufactured by Delta Water Company, Industrial Zone-1, Alexandria, Egypt; and lastly, iii) Magnetic-BW_2; brackish water following magnetization via passing 3 inch static magnetic unit; 0.75 mT; manufactured by Magnetic-Technologies Company, Dubai, UAE. The experiment was performed at Agricultural Experimental Station belonged to Desert Research Centre, Ras Sidr District, South Sinai Governorate, Egypt through winter seasons of 2019/20 and 2020/21.

The two tested factors were tripled and designed in split-plot layout beneath drip irrigations system where the three water treatments and four examined varieties were assigned in main and sub-plot, respectively. The area of the experiment is located in the Suez Gulf and coast of the Red Sea (29º60'28" N latitude and 32º68'96" E longitude). The soil of the experimental site as well as irrigation water was analyzed according to **[16].** Table 1 exposed that soil of the experimental location was sandy loam, saline and deficient in organic matter and NPK content. Also, saline water was used as irrigation system **[17].**

2.1 Sowing methods and design of experiment

The soil of the experimental site was double time ploughed, ridged at 0.60 meter apart and sectioned into main and sub-plots with area 48 m^2 and 12 m^2, respectively. Through seedbed preparation, seventy-five kg fed^{-1} calcium superphosphate (15.5% P_2O_5) was applied. Quinoa seeds tested varieties (Q1, Chibayi, Q37 and KVL) were sown on the second week of November 2018/19 and 2019/20 winter seasons in lines; 50-cm apart and 20-cm between seed hills. Drip irrigation was applied immediately after planting and as plants demanded during the experiment’s time.

Table 1. Physical, chemical and mechanical analysis of soil and irrigation water before planting (Hozaynet *al.* 2018).

Parameter	Soil depth (cm) 0-30	Soil depth (cm) 30-60	Irrigation water
Soil physical properties			
pH	7.66	7.00	8.60
EC (dSm^2)	8.65	7.90	9.68
Organic matter (%)	1.70	1.23	…
Particle size distribution			…
Sand (%)	81.28	86.08	..
Clay (%)	10.67	6.33	..
Silt (%)	8.05	7.59	..
Texture	Sandy loam		..
Soil chemical properties			
Soluble cations (mq/100g)			
Ca^{+2}	38.22	30.82	23.54
Mg^{+2}	27.44	22.00	24.48
Na^{+}	58.33	65.80	40.05
K^{+}	2.01	0.08	0.14
Soluble anions (mq/100g)			
CO^{-2}_3	0.00	0.00	0.00
HCO^{-}_3	3.44	2.00	4.50
SO^{-2}_4	58.93	65.20	29.23
Cl^{-}	64.14	51.50	48.94

Thinning was performed after three weeks from sowing to obtain two plants per hill on one side of the ridge. Addition of ammonium sulfate (20.60 N%) at the rate (45 kg N fed^{-1}) was done as nitrogen fertilizer by four equal doses beginning from three weeks after sowing till flowering. While, potassium sulfate (48 % K_2O) was added as potassium fertilizer at the rate of 50 kg fed^{-1} after four weeks from planting. Other recommended agricultural practices for Quinoa culturing were applied following Agriculture Research Centre leaflet beneath this region circumstances. Experimental design was displayed in Figure1.

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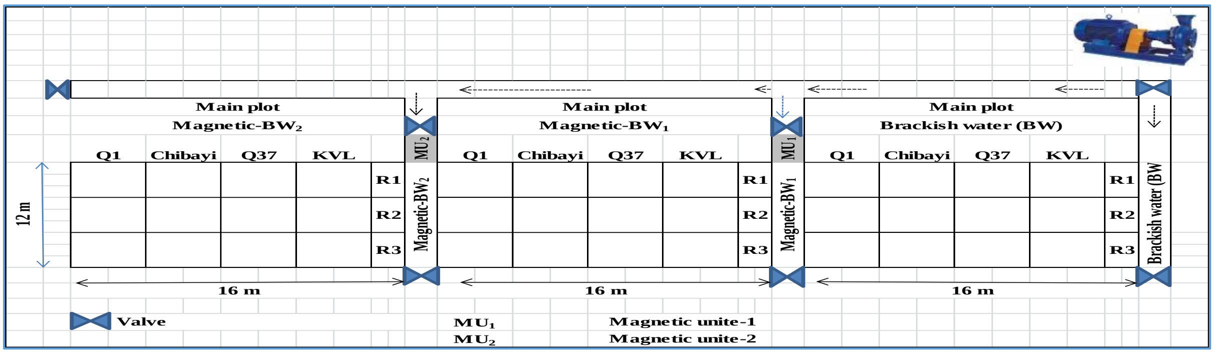

Figure 1. Experimental design.

2.2 Data recorded

2.2.1 Vegetative growth at 85 days after sowing (85 DAS): After eighty-five days from sowing (DAS), 10 plants were randomly gathered from each plot to report vegetative growth parameters (i.e., plant height (cm), stem and total plant (g plant^{-1}), inflorescence and leaves (number plant^{-1}), and dry matter of leaves). Additionally, leaf area (LA; dm^2 plant^{-1}) was measured in accordance with the leaf disc method **[18].**

2.2.2 Total Chlorophyll: SPAD Chlorophyll meter was used to determine the total Chlorophyll in leaves **[19].**

2.2.3 Micro-morphological investigation:

Stem and lamina from the 3rd node were cross-sectioned using hand microtome at 10-20 µm then preserved and fixed in FAA. After that, sections were double stained using safranin and light green, mounted by Canada Balsam according to the conventional method [**20**]. The anatomical features were described according to Terminology of **[21].** Photomicrographs were obtained using a Reichert Microstar IV microscope with digital camera (Cannon Power Shot G12). The microscopic examination was taken place at Plant Taxonomy Research Laboratory, Botany Department, Faculty of Science, Ain Shams University, Cairo, Egypt.

2.2.4 Chemical analysis in shoot: the concentration Macro-elements (Na, K, Mg, Ca and N) as well as micro-ones (Cu, Fe, Mn and Zn) were assessed in dry leaves at 85 DAS according to **[16].** Total nitrogen was estimated by using Micro-Kjeldahl method. Calcium, potassium, and sodium were defined using flame photometer. While, the determination of Fe, Cu, Mg, Mn, and Zn contents was achieved using the Atomic absorption spectrophotometer.

2.2.5 Quinoa yield and its components: a random sample of 10 plants from each plot was taken at harvest time, to determine some yield indicators such as plant height (cm), panicle length and width (cm), panicle seed weight and 1000-seed weight (g). Plants of two meters square in each plot were harvested, dried beneath sunshine for seven days, while seeds were cleaned after detached from the panicles, then the grains yield (kg fed^{-1}; 4200 m^2) was calculated.

2.3 Statistical analysis

Obtained data were statistically analyzed using MSTAT-C computer package **[22].** The least significant difference ($LSD_{5\%}$) test was applied to compare among the means.

3 Results

3.1 Vegetative growth and total chlorophyll contents at 85 days after sowing (85 DAS)

Significant variations among tested four quinoa varieties and three magnetized water treatments and their interaction were recorded in all tested growth parameters at 85 DAS; plant height (cm), inflorescence, leaves (no $plant^{-1}$) and leaf area (LA) in dm^2 $plant^{-1}$ (Table 2). On the other side, dry matter of leaves, stem and total plant (g $plant^{-1}$) besides total chlorophyll (SPAD) in leaves were displayed in Table 3.

Concerning irrigation water treatments, obtained data demonstrated that irrigation with M-BW_1 or M-BW_2 treatments exceeded irrigation with BW in all examined growth parameters.

Table 2. Plant height, inflorescence and leaves (no. $plant^{-1}$) and leaf area (dm^2 $Plant^{-1}$) of some quinoa varieties under magnetic brackish water treatments at 85 DAS

Treatment Water	Variety	Plant height (cm)	Inflorescence (no. $plant^{-1}$)	Leaves (no. $plant^{-1}$)	LA (dm^2 $plant^{-1}$)
Brackish water (BW)	Q1	44.20	15.00	13.80	60.61
	Chibayi	47.40	18.00	14.40	67.93
	Q37	45.33	22.00	14.20	55.74
	KVL	52.20	28.00	17.00	64.44
Magnetic-BW_1 (M-BW_1)	Q1	52.40	22.00	15.20	61.50
	Chibayi	49.80	26.00	16.47	70.07
	Q37	47.25	22.00	16.40	66.71
	KVL	54.40	38.00	17.20	72.48
Magnetic-BW_2 (M-BW_2)	Q1	45.00	21.67	15.13	72.81
	Chibayi	54.20	30.00	18.10	70.16
	Q37	50.00	32.00	16.93	61.92
	KVL	54.80	35.00	19.00	67.00
F test		**	**	Ns	**
$LSD_{5\%}$		2.69	3.40	1.98	0.14
Water treatments	BW	47.28	20.75	14.85	62.18
	M-BW_1	50.96	27.00	16.32	67.69
	M-BW_2	51.00	29.67	17.29	67.97
F test		**	**	**	**
$LSD_{5\%}$		0.81	0.51	0.54	0.05
Variety	Q1	47.20	19.56	14.71	64.97
	Chibayi	50.47	24.67	16.32	69.38
	Q37	47.53	25.33	15.84	61.46
	KVL	53.80	33.67	17.73	67.97
F test		**	**	**	**
$LSD_{5\%}$		1.55	1.96	1.14	0.08
$CV_{\%}$		3.14	7.67	5.15	2.56

CV%: Coefficient of Variation; LSD: Least significant difference; * Significant at $P < 0.05$; ** Significant at $P < 0.01$

The average percent of improvements achieved by both magnetically brackish-water treatments compared to irrigation with untreated brackish water amounted to 7.82, 36.55, 13.16 and 9.09% (Table 2), 25.43, 24.74, 32.77, 25.59 and 21.22% (Table 3) in the above-mentioned properties, respectively. In addition, respectable variances were recorded among examined Quinoa varieties where KVL registered in the first order for obtaining the highest values in the above-mentioned growth properties followed by Q37, Chibayi and Q1, respectively. Generally, irrigation with M-BW_1 or M-BW_2 treatments caused a positive impact on the growth and total chlorophyll of the tested four varieties compared to irrigation with brackish water.

Table 3.Total chlorophyll (SPAD), dry matter of plant organs (g plant^{-1}) caused by some quinoa varieties under magnetic brackish water treatments at 85 DAS.

Treatment		Dry matter (g plant^{-1};75 DAS)				Total chlorophyll (SPAD)
Water	Variety	Leaves	Stem	Panicles	Plant	
Brackish water (BW)	Q1	2.59	2.36	0.30	5.24	53.38
	Chibayi	2.91	3.24	0.48	6.63	57.48
	Q37	2.72	3.17	0.37	6.26	54.42
	KVL	3.40	3.50	0.58	7.47	65.14
Magnetic-BW_1 (M-BW_1)	Q1	2.80	3.02	0.35	6.17	62.71
	Chibayi	3.57	3.84	0.54	7.95	66.41
	Q37	3.51	3.81	0.55	7.88	63.68
	KVL	4.00	4.31	0.75	9.06	70.32
Magnetic-BW_2 (M-BW_2)	Q1	3.26	3.20	0.47	6.93	71.59
	Chibayi	4.00	4.16	0.64	8.80	74.66
	Q37	3.64	3.89	0.56	8.10	73.44
	KVL	4.36	4.36	0.72	9.44	75.81
F test		*	**	**	**	**
$LSD_{5\%}$		**0.14**	**0.01**	**0.17**	**3.27**	**2.52**
Water treatment	BW	2.90	3.07	0.43	6.40	57.60
	M-BW_1	3.47	3.75	0.55	7.76	65.78
	M-BW_2	3.82	3.90	0.60	8.32	73.88
F test		**	**	**	**	**
$LSD_{5\%}$		**0.11**	**1.01**	**0.09**	**0.93**	**0.83**
Variety	Q1	2.88	2.86	0.37	6.12	62.56
	Chibayi	3.49	3.75	0.55	7.79	66.18
	Q37	3.29	3.62	0.49	7.41	63.85
	KVL	3.92	4.06	0.68	8.66	70.42
F test		**	**	**	**	**
$LSD_{5\%}$		**0.08**	**0.00**	**0.10**	**1.89**	**1.45**
$CV_{\%}$		**2.43**	**1.94**	**1.36**	**2.89**	**2.23**

CV%: Coefficient of Variation; LSD: Least significant difference; * Significant at P < 0.05; ** Significant at P < 0.01

3.2 Anatomical studies

3.2.1 Stem anatomy

Different anatomical characters comprising thickness of various cells and layers were measured and represented in cumulative Table (4) and the major different aspects were showed in plate (1).

The results shows that all varieties of quinoa showed the same anatomical background of angular stem outline with ridge and furrow, thin cuticle, radially elongated epidermis, clavatetrichomes, cortex of three types of tissues *viz*. angular collenchyma (under ridge), chlorencyma (under furrow), polyhedral parenchyma. Vascular supply in form of dissected siphonstele. Secondary phloem (sieve tube cell, companion cell, phloem parenchyma in fasicularand interfasicular region. Secondary xylem (xylem vessels, fiber, xylem parenchyma). Pith polyhedral parenchyma. Presence of druses crystals.

Quinoa plants irrigated with M-BW_1 or M-BW_2 treatments had also grown with more height values as compared those irrigated with brackish water (BW).

Table 4. Values in microns of definite anatomical properties in transverse sections among the stems of some quinoa varieties magnetic brackish water treatments at 85 DAS

Treatment	Q1			Chibayi			Q37			KVL		
Stem anatomy character	BW	M-BW_1	M-BW_2	BW	M-BW_1	M-BW_2	BW	M-BW_1	M-BW_2	BW	M-BW_1	M-BW_2
Epidermis thickness	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cortex thickness (ridge)	0.32	0.35	0.37	0.31	0.41	0.35	0.32	0.41	0.37	0.35	0.36	0.45
Cortex thickness (furrow)	0.20	0.22	0.21	0.10	0.19	0.15	0.18	0.19	0.23	0.15	0.20	0.18
Collenchyma thickness (ridge)	0.09	0.11	0.10	0.10	0.13	0.12	0.08	0.12	0.17	0.07	0.09	0.11
Chlorenchyma thickness (furrow)	0.04	0.06	0.06	0.04	0.05	0.05	0.04	0.07	0.07	0.04	0.06	0.05
Parenchyma thickness (ridge)	0.16	0.20	0.20	0.10	0.15	0.12	0.21	0.26	0.29	0.20	0.28	0.31
Parenchyma thickness (furrow)	0.09	0.14	0.12	0.07	0.01	0.09	0.11	0.12	0.12	0.11	0.19	0.17
Vascular cylinder thickness	0.27	0.29	0.31	0.23	0.28	0.25	0.33	0.36	0.28	0.27	0.42	0.29
Phloem thickness	0.08	0.09	0.09	0.07	0.09	0.08	0.07	0.08	0.09	0.05	0.11	0.08
Xylem thickness	0.12	0.23	0.15	0.11	0.17	0.12	0.13	0.19	0.18	0.12	0.19	0.14
Average vessel diameter	0.01	0.02	0.02	0.02	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.03
Pith width	2.60	2.90	2.70	2.65	2.80	2.77	2.66	2.95	2.81	2.31	2.90	2.85

3.2.2 Lamina Anatomy:

Because of an expressive change in the growth of leaves, quinoa irrigated with magnetized water showed wide leaves as in table (5) and plate (1) and those with BW had narrow leaves. These altered leaves were further examined using an optical microscope showed that, mesophyll is dorsiventral, palisade tissue are elongated with one to two layers in varieties irrigated with BW and increased to three to four of both magnetically brackish water (M-BW_1 and M-BW_2) treatments. Rows of spongy tissue are 4-5 in quinoa irrigated with BW as compared with 5-6 rows under M-BW_1 and M-BW_2. In mid rib region, the number of rows of different tissue of collenchyma, parenchyma and chlorenchyma increased in quinoa irrigated with both M-BW treatments (table 5). These investigations demonstrated that the leaves of the plants irrigated with magnetic treated water had more palisade thickness to spongy of mesophyll with NaCl concentration increase (Plate 1). These quinoa leaves also showed a larger cell structure.

Table 5. Values in microns of definite anatomical properties in transverse sections among the lamina of some quinoa varieties under magnetic brackish water addresses at 85 DAS.

Treatment	Q1			Chibayi			Q37			KVL		
Stem anatomy character	BW	M-BW_1	M-BW_2	BW	M-BW_1	M-BW_2	BW	M-BW_1	M-BW_2	BW	M-BW_1	M-BW_2
Midrib thickness	1.01	1.12	0.98	0.92	1.16	1.20	1.00	1.10	0.92	0.82	1.44	1.20
Wing thickness	0.16	0.36	0.30	0.16	0.24	0.20	0.13	0.30	0.36	0.20	0.00	0.30
Adaxial epidermis thickness	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01
Abaxial epidermis thickness	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Adaxial collenchyma thickness	0.01	0.14	0.13	0.13	0.18	0.11	0.14	0.18	0.20	0.09	0.20	0.23
Abaxial collenchyma thickness	0.05	0.07	0.10	0.09	0.16	0.08	0.12	0.15	0.10	0.08	0.13	0.18
Palisade tissue thickness	0.10	0.18	0.11	0.06	0.13	0.09	0.08	0.13	0.10	0.11	0.14	0.13
Spongy tissue thickness	0.13	0.17	0.16	0.08	0.14	0.10	0.07	0.09	0.08	0.08	0.15	0.12
Midvein vascular bundle thickness	0.18	0.20	0.20	0.20	0.20	0.20	0.24	0.26	0.24	0.12	0.26	0.18

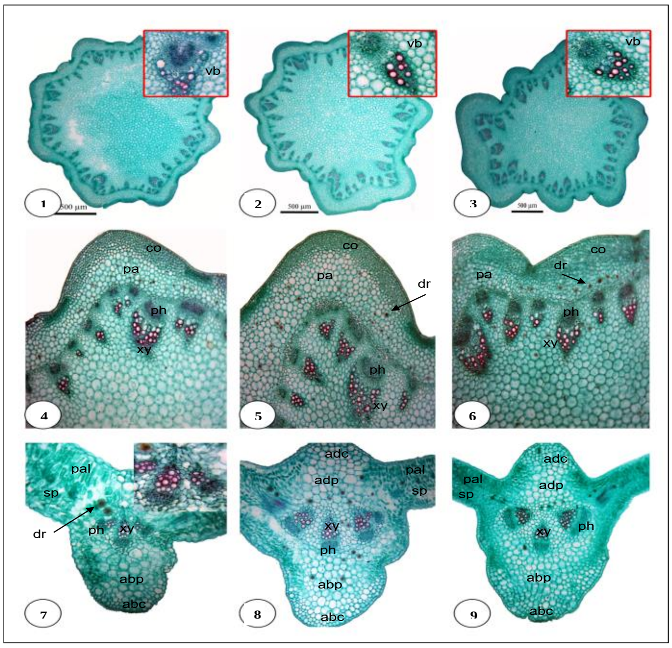

Plate 1. Cross section in stem showing outline and pith width; 1) BW, 2) MBW_1, 3) MBW_2, Cross section in stem (10×), 4) BW, 5) MBW_1, 6) MBW_2, cross section of leaf (10×), 7) BW, 8) MBW^1, 9) MBW^2vb- vascular bundle, pa-parenchyma, co- collenchyma, ph- phloem, xy- xylem, pal- palisade, spo- spongy, adc- adaxial collenchyma, adp- adaxial parenchyma, abc- abaxial collenchyma, abp- abaxial parenchyma, dr- druses crystal.

3.3 Macro and Micro-elements in leaves at 85 DAS

Table 6 showed that the tested four quinoavarieties (Q1, Chibayi, Q37 and KVL) gave more values of macro and micro-nutrients in leaves at 85 DAS, except Na, Zn, and Cu under irrigation with both magnetic-brackish treated water than irrigation with BW treatment. As an average of the four Quinoa varieties, the percent of improvement over control reached 33.20, 16.18, 14.24, 17.70, 30.59, and 46.07% in leaf contents of N, Ca, Fe, K, Mg, and Mn, respectively compared to untreated brackish water addressing. Contrarily, reduced values were reported in leave contents of Na, Zn and Cu by 74.33, 22.59 and 43.33%, respectively. Additionally, significance differences were recorded among tested varieties, which KVL attended in the first order for giving more values in above mentioned growth properties followed, by Q37, Chibayi, and Q1, respectively. Irrigation with M-BW_1 or M-BW_2 treatments caused positive impact on macro and micro-nutrients in leaves at 85 DAS of tested four varieties compared to irrigation with brackish water.

Table 6. Macro-elements (%) and micro-elements in leaves (ppm) of some quinoa varieties under magnetic brackish water treatment at 85 DAS

Treatment		Macro-elements in leaves (%) at 85 DAS					Micro-elements in leaves (ppm) at 85 DAS			
Water	**Variety**	**N**	**K**	**Mg**	**Na**	**Ca**	**Fe**	**Mn**	**Zn**	**Cu**
Brackish water (BW)	**Q1**	1.50	2.60	0.18	1.55	1.40	94.00	53.00	190.00	6.00
	Chibayi	1.80	1.95	0.27	1.58	1.35	111.00	69.00	175.00	4.50
	Q37	1.50	2.25	0.20	1.80	1.38	121.00	60.00	175.00	6.00
	KVL	1.30	2.10	0.20	1.18	1.40	113.00	47.00	177.00	7.50
Magnetic-BW_1 (MBW_1)	**Q1**	1.60	2.65	0.20	0.43	1.50	135.00	75.00	143.00	4.00
	Chibayi	2.30	2.55	0.29	0.45	1.60	113.00	74.00	144.00	3.00
	Q37	1.80	2.50	0.23	0.50	1.60	128.00	95.00	147.00	3.00
	KVL	1.75	2.45	0.26	0.36	1.75	114.00	74.00	153.00	3.50
Magnetic-BW_2 (MBW_2)	**Q1**	1.80	2.95	0.22	0.33	1.60	148.00	91.00	146.00	3.00
	Chibayi	2.50	2.75	0.31	0.30	1.40	114.00	79.00	148.00	4.50
	Q37	2.30	2.65	0.29	0.38	1.65	135.00	98.00	119.00	3.20
	KVL	2.20	2.45	0.42	0.38	1.75	116.00	83.00	110.00	3.00
F test		**	**	**	**	**	**	**	**	**
$LSD_{5\%}$		**0.07**	**0.05**	**0.02**	**0.03**	**0.04**	**1.87**	**1.53**	**2.73**	**0.23**
Water	**BW**	1.53	2.23	0.21	1.53	1.38	109.75	57.25	179.25	6.00

treatment	**MBW₁**	1.86	2.54	0.25	0.44	1.61	122.50	79.50	146.75	3.38
	MBW₂	2.20	2.70	0.31	0.35	1.60	128.25	87.75	130.75	3.43
F test		**	**	**	**	**	**	**	**	**
LSD5%		**0.05**	**0.05**	**0.94**	**0.03**	**0.02**	**0.24**	**0.35**	**1.13**	**0.18**
Variety	**Q1**	1.63	2.73	0.20	0.77	1.50	125.67	73.00	159.67	4.33
	Chibayi	2.20	2.42	0.29	0.78	1.45	112.67	74.00	155.67	4.00
	Q37	1.87	2.47	0.24	0.89	1.54	128.00	84.33	147.00	4.07
	KVL	1.75	2.33	0.29	0.64	1.63	114.33	68.00	146.67	4.67
F test		**	**	**	**	**	**	**	**	**
LSD5%		**0.04**	**0.03**	**0.01**	**0.02**	**0.02**	**1.08**	**0.89**	**1.58**	**0.13**
CV%		**2.35**	**1.99**	**3.81**	**2.68**	**1.47**	**0.91**	**1.19**	**1.04**	**3.07**

NS: not significant * Significant at P < 0.05 ** Significant at P < 0.01

4.4 Quinoa yield and its components at harvest:

At harvest date, table 7 and plate 2 shows significant variation among tested four varieties, magnetized water treatments and their interaction on quinoa yield and its components. Concerning irrigation water treatments, obtained results show that irrigation with both magnetically brackish water (M-BW_1 or M-BW_2) overcomes irrigation with untreated brackish water (BW) in quinoa yield and its components. As an average of both M-BW_1 and M-BW_2 treatments, the percentage of improvement comes to 9.59% in plant height (cm), 10.33% in panicle length (cm), 13.54% in panicle width (cm), 27.73% in panicle weight (g), 22.36% in panicle seed weight (g) and 2.22% in 1000-seed weight (g); Table 7. These improvements in yield components were reflected in improving grains yield (kg fed^{-1}), where the increase reached 8.28%. Additionally, significant differences were recorded among tested varieties, where KVL variety attended in the first order for giving more values in above yield and yield components properties followed by Q37, Chibayi and Q1, respectively. Irrigation with M-BW_1 or M-BW_2 caused a positive impact on yield and yield components of the examined four varieties compared to irrigation with brackish water.

Table 7. Plant height, panicles characters and grains yield (kg fed^{-1}; fed=4200 m^2) of some quinoa varieties under magnetized brackish water treatments at harvest (Average of 2019/20 and 2020/21 winter seasons)

Treatment		Plant height (cm)	Panicle character (s)				1000-seed wt. (g)	Seed yield (kg fed^{-1})
Water	Variety		Length (cm)	Width (cm)	Weight (g)	Seeds wt. (g)		
Brackish water (BW)	**Q1**	55.67	17.18	2.93	16.60	12.80	11.54	448.00
	Chibayi	71.00	22.33	3.40	22.13	16.00	12.02	504.57
	Q37	67.00	21.60	3.20	21.60	15.00	11.99	506.04
	KVL	74.08	24.58	3.63	29.10	20.90	13.79	704.73
Magnetic-BW¹ (MBW¹)	**Q1**	59.08	19.75	3.37	20.20	16.90	11.58	551.87
	Chibayi	75.83	24.00	3.87	28.00	19.30	12.87	611.39
	Q37	73.33	22.00	3.50	26.80	18.70	12.19	601.83
	KVL	81.50	26.60	4.00	37.00	22.70	13.74	774.41
Magnetic-BW² (MBW²)	**Q1**	63.33	20.20	3.50	21.50	17.30	11.59	556.84
	Chibayi	78.33	25.33	3.87	28.27	20.00	12.92	637.57
	Q37	71.83	24.00	3.80	26.60	18.30	12.25	615.50
	KVL	83.58	27.20	4.00	40.10	25.13	13.73	768.15
F test		*	*	*	**	**	*	*
LSD5%		**3.30**	**1.30**	**0.42**	**1.27**	**1.03**	**0.86**	**35.54**
Water treatment	**BW**	66.94	21.42	3.29	22.36	16.18	12.33	540.84
	MBW₁	72.44	23.09	3.68	28.00	19.40	12.60	634.88
	MBW₂	74.27	24.18	3.79	29.12	20.18	12.62	644.51
F test		*	**	**	**	**	*	**
LSD5%		**1.97**	**0.76**	**0.12**	**0.30**	**0.37**	**0.56**	**5.86**

Variety	**Q1**	59.36	19.04	3.27	19.43	15.67	11.57	518.90
	Chibayi	75.06	23.89	3.71	26.13	18.43	12.60	584.51
	Q37	70.72	22.53	3.50	25.00	17.33	12.14	574.46
	KVL	79.72	26.13	3.88	35.40	22.91	13.75	749.10
F test		**	**	**	**	**	**	**
LSD5%		**1.90**	**0.75**	**0.24**	**0.73**	**0.59**	**0.50**	**20.52**
CV%		**2.7**	**3.30**	**6.64**	**2.79**	**3.22**	**3.97**	**3.42**

NS: not significant * Significant at P < 0.05 ** Significant at P < 0.01

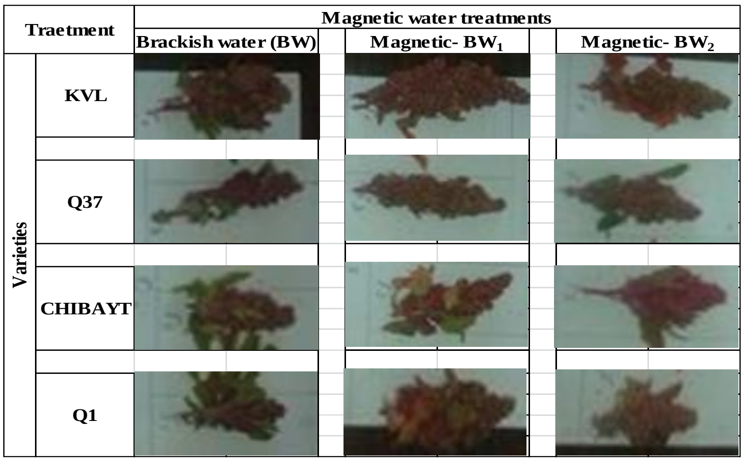

Plate 2. Panicle of Quinoa varieties under different magnetized brackish water treatments at harvest.

4. Discussion

4.1 Vegetative growth and total chlorophyll contents at 85 days after sowing (85 DAS)

The positive effects of irrigation with magnetized brackish-water on growth criteria of tested quinoa varieties compared to irrigation with brackish water may be due to the correction of brackish water and improving soil properties **[17]**. Magnetic treatment of irrigation water is a recognized technique for improving water and soil physiochemical properties **[2, 5, 8-13].** These changes in water and soil physiochemical properties during the vegetative growth of plants, better assimilation of nutrients and fertilizers in plants can induced as a result of increased ability of soil to get rid of salts, thus plants overcome the influence of salinity stress. In this concern, **[1]** deduced that treatments of magnetized water reduce the hydration of salt ions and colloids, having a positive impact on salt solubility rather than enhancing coagulation and salt crystallization. Consequently, this resulted an increase in the available nutrients; phosphorus, potassium and magnesium, which led to elevating plant growth, yield and yield components **[6, 7, 12]**. The better growth of quinoa plants under magnetic treatment was ascribed to easy entry of water and availability of minerals in soil via the cell membrane of plants; the magnetic treatment elevated the solubility of salts and minerals, which are needed for cell division and elongation through the plant growth **[24].**in addition to the polarization of dipoles and activation of ions in the living cells **[25].**

The rise in the photosynthetic pigments of quinoa varieties leaves resulting from magnetized water treatments is closely related to the increments in the concentrations of certain elements such as (N, Fe, and Mg Table 6). Several investigators confirm that Fe and Mg function in the synthesis of chloroplastic protein thus they may play an essential role in chlorophyll synthesis **[26, 27].**

4.2 Anatomical studies

4.2.1 Stem anatomy

Generally, varieties with both magnetized brackish water treatments showed increases in stem diameters, layers of collenchyma (that reduce the rate of evaporation), increase of parenchyma and the number of vascular bundles and also the diameter of vessels. The number of crystals also increases. In some treatment two distinct types of crystals occur prismatic and druses. Plant crystals are composed endogenously formed oxalic acid, which combines with Ca from the environment **[28].** The formation of most crystals was biologically induced. The crystals may have functions in eliminating excess sulfur, calcium and magnesium guarding the plants versus herbivory, in addition to detoxifying aluminum and other heavy metals. Similar positive trends were recorded with results on potato, wheat and canola **[2, 9, 10, 11. 29].**

4.2.2 Lamina anatomy

In general, salinity induced morphological and anatomical changes. The Magnetized water caused a significant reduction of soil salinity, so MW irrigation can be deemed as a beneficial technique for better agricultural output. Similar positive trends were recorded with results on potato **[9]**, wheat **[11],** and canola **[29].**

4.3 Macro and Micro-elements in leaves at 85 DAS

Application of magnetically brackish water caused positive effects on some elements like (NK, and Ca) and negative on others (i.e., Na and Cl) compared to irrigation with brackish water. Similar trends were recorded on sunflower, alfalfa, and barley **[10, 18, 29].** The magnetized water treatments boosted the availability of minerals in soil via elevated solubility of salts and minerals needed for cell division and elongation through plant growth. An increase of Ca, Mg, and NPK concentration in many plants (i.e., wheat, barley, sunflower, canola, potato, tomato, and strawberry) under magnetic treatments compared to control treatment; **[8, 9, 29]**. Magnetized water induced an elevation in all macro and micro-elements content except sodium **[2]**. This is attributed to that sodium is one of the paramagnetic elements, which have a tiny positive susceptibility to magnetic fields, in contrast to other elements which are diamagnetic; little repelled by a magnetic field.

Irrigation with magnetized-brackish water caused a clear and significant, reduction of Na concentration in leaves, this may be helpful in reduction of sodium toxicity at cell level, either by hindering the entry of sodium at the membrane level or by minimizing absorption of sodium by plant roots **[5]**. Alternatively, the decreasing sodium concentration in quinoa leaf may be related to dilution of salts when irrigated with magnetized saline water.

4.4 Quinoa yield and its components at harvest:

Yield and yield components are considered the last vessel (both quantitative and qualitative) in which the effect of treatments on the properties of soil and irrigation water, and then the morphology criteria during the period of vegetative growth and its content of nutrients, which are reflected by the invisible physiological changes. The positive effect of magnetic treatments for partial desalination of saline irrigation

water and soil **[2. 10, 11,17,28]**, led to improving macro and micro-growth parameters (Table 3-5) which was reflected in the improvement of yield and yield components at harvest (Table 6). Similar results were recorded on many crops either under irrigation water and/or soil salinity stresses i.e., sunflower, wheat, barley, alfalfa**,** sugar beet, faba bean **[2. 10, 11,12, 17, 29-33].**

5 Conclusions

The study indicated that the application of magnetically treated brackish water caused clear and beneficial effects on growth, leaf and stem anatomy, pigments, chemical constituents, and productivity of quinoa plants. Under this status, it is deduced that the application of magnetic water technology with the combination of other factors (i.e., crops moderate for salinity stress) can be used as an efficient strategy for mitigating salinity stress and progressing soil and brackish water. The results showed that the KVL variety attended in the first order for giving more values in the above yield and yield components properties followed by Q37, Chibayi, and Q1, respectively.

References

[1] Hilal, M.H. and M.M. Hilal,. Application of magnetic technologies in desert agriculture II – Effect of magnetic treatments of irrigation water on salt distribution in olive and citrus fields and induced changes of ionic balance in soil and plant .Egypt . J. Soil .Sci , 40(3), 423 – 435 (2000).

[2] Hozayn, M; Sahar M. Ismail; Abd El-Monem A.A. and Darwish M.M. Magnetically treated brackish water: new approach for mitigation salinity stress on sunflower productivity and soil properties under South Sinai region, Alex. Sci. Exchange J., 40 (3), 451-470 (2019 a).

[3] Kronenberg KJ. Magneto hydrodynamics: The effect of magnets on fluids. GMX international. (2005).

[4] Maheshwari, B.L. and H.S. Grewal,. Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity. Agric. Water Manag., 96, 1229–1236 (2009).

[5] Mohamed, M.F., Maha, M.S.A., Khalifa, R.K.M., Ahmed, A.G., Hozayn, M. Effect of arginine and GA_3 on growth, yield, mineral nutrient content and chemical constituents of faba bean plants grown in sandy soil conditions. *International* Journal of ChemTech Research, 8 (12), 187-195 (2015).

[6] Hozayn, M., Abdallah, M.M.S., Abd El-Monem, A.A. Effect of proline on growth, yield, nutrient and amino acid contents of barley (*Hordeumvulgare* L.) irrigated with moderate saline water. *International Journal of ChemTech Research*, 8 (12), 772-783 (2015 a).

[7] Hozayn, M., El-Bassiouny, H.M.S., Abd El-Monem, A.A., Abdallah, M.M.. Applications of magnetic technology in agriculture, a novel tool for improving water use efficiency and crop productivity: 2. Wheat. International

Journal ofChemTech Research, 8 (12), 759-771 (2015 b).

[8] Hozayn M.; Abdallha, M.M.; Abd El-Monem A.A.; El-Saady, A.A. and Darwish M.A. Applications of magnetic technology in agriculture: A novel tool for improving crop productivity (1): Canola. African Journal of Agricultural Research, 11(5), 441-449 (2016 a).

[9] Hozayn, M., Salama, A. M., Abd El-Monem, A. A., and Hesham, A. F. The impact of magnetized water on the anatomical structure, yield and quality of potato (*Solanumtuberosum* L.) grown under newly reclaimed sandy soil. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 7(3), 1059-1072 (2016).

[10] Hozayn, M., Ahmed, A.A., El-Saady, A.A., Abd-Elmonem, A.A. Enhancement in germination, seedling attributes and yields of alfalfa (*Medicagosativa* L.) under salinity stress using static magnetic field treatments. *EurAsian Journal of BioSciences*, 13 (1), 369-378 (2019 b).

[11] Mahmoud, M., Salim, M. A., El-Monem, A., Amany, A., and El-Mahdy, A. A. Effect of magnetic brackish-water treatments on morphology, anatomy and yield productivity of wheat (*Triticumaestivum*). Alexandria Science Exchange Journal, 40, 604-617 (2019).

[12] Hozayn, M., and Ahmed, A.A. Effect of magneto-priming by tryptophan and ascorbic acid on germination attributes of barley (*Hordeumvulgare*, L.) under salinity stress*EurAsian Journal of BioSciences*, 13 (1), 245-251(2019).

[13] Ben Hassen, H., Hozayn, M., Elaoud, A., and AttiaAbdd El-monem, A. Inference of magnetized water impact on salt-stressed wheat. Arabian
Journal for Science and Engineering, 45, 4517-4529 (2020).

[14] FAO Origin and History, International Year of Quinoa 2013. Available online: http://www.fao.org/quinoa2013/what-is-quinoa/nutritional-value/en/?no_mobile=1 (accessed on 23 August 2019)

[15] Repo-Carrasco, R.; Espinoza, C.; Jacobsen, S.E. Nutritional value and use of the Andean crops quinoa (*Chenopodiumquinoa*) and kañiwa (Chenopodiumpallidicaule). Food Rev. Int., 19, 179–189 (2003).

[16] Chapman, H. D., and Pratt, P. F. Methods of analysis for soils, plants and waters. Soil Science, 93(1), 68 (1962).

[17] Hozayn M., Amal A. A. EL-Mahdy and Zalama M.T. Magneto-priming for improving germination, seedling attributes and field performance of barley (*Hordeumvulgare* L.) under salinity stress. Middle East Journal of AgricultureResearch, 7(3), 1006-1022 (2018).

[18] Lima, J. F., Peixoto, C. P., and Ledo, C. A. S. Índices fisiológicos e crescimento inicial de mamoeiro (Caricapapaya L.) em casa de vegetação. Ciência e Agrotecnologia, 31,(5), 1358-1363 (2007).

[19] Konica, M.O., Chlorophyll Meter SPAD-502 Plus - A lightweight handheld meter for measuring the chlorophyll content of leaves without causing damage to plants. (2012). URL:http://www.konicaminolta.com/instruments/download/catalog/color/pdf/spad502plus_e1.pdf (as of: Apr/13).

[20] Johanson, D.A. Plant Microtechnique. New York Book Company, 523(1940).

[21] Metcalfe CR and Chalk L. Anatomy of the dicotyledons. Clarendon Press; Oxford (1957).

[22] Freed, R.S.P., S. Einensmith, S. Gutez, D. Reicosky, V.W. Smail and P. Wolberg,.MSTAT-C analysis of agronomic research experiments. Michigan Univ. East Lansing, USA. (1989).

[23] Surendran U., Sandeep O., Joseph E.J.,. The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics. Agricultural Water Management, 178, 21-29 (2016).

[24] Barefoot, RR., Reich, CS. The calcium factor: The scientific secret of health and youth. South eastern, PA: Triad Marketing, 5th edition (1992).

[25] Naz, A., Jamil, Y., Iqbal, M., Ahmad, M. R., Ashraf, M. I., and Ahmad, R. Enhancement in the germination, growth and yield of okra (*Abelmoschusesculentus*) using pre-sowing magnetic treatment of seeds.(2012).

[26] Walker, C. J., and Weinstein, J. D. The magnesium-insertion step of chlorophyll biosynthesis is a two-stage reaction. Biochemical Journal, 299(1), 277-284 (1994).

[27] Zude, M., Alexander, A., and Lüdders, P. Influence of FeEDDHA and sugar acid derivates on curing iron chlorosis in citrus. Gesundepflanzen51, 125-129 (1999).

[28] Franceschi, V. R., and Nakata, P. A. Calcium oxalate in plants: formation and function. Annu. Rev. Plant Biol., 56, 41-71 (2005).

[29] Hozayn, M., El-Dahshouri, M. F., Salama, A. M., Abdelraouf, R. E., and Ahmed, A. Z. Influence of magnetic brackish-water treatments on growth, anatomical structure, yield and quality of sugar beet (*Beta vulgaris* L.). Plant Archives, 20(2), 8271-8278 (2020).

[30] Mohamed, A. I., and Ebead, B. M. Effect of magnetic treated irrigation water on salt removal from a sandy soil and on the availability of certain nutrients. International Journal of Engineering, 2(2), 2305-8269 (2013).

[31] Hozayn, M., Elaoud, A., AttiaAbd El-Monem, A., and Ben Salah, N. Effect of magnetic field on growth and yield of barley treated with

different salinity levels. Arabian Journal of Geosciences, 14(8), 701 (2021).

[32] Abdelraouf, R. E., El-Shawadfy, M. A., Dewedar, O. M., and Hozayn, M. Improving yield and water productivity of canola under sprinkler irrigation and high frequency of N-fertigation. (2021).

[33] Mghaiouini, R., Abderrazzak, G., Benzbiria, N., Elaoud, A., Garmim, T., Belghiti, M. E., and El Bouari, A. Elaboration and physico-mechanical characterization of a new eco-mortar composite based on magnetized water and fly ash. Journal of Ecological Engineering, 21(4), 245-254 (2020).