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INFLUENCE OF MAGNETIC BRACKISH-WATER TREATMENTS ON GROWTH, ANATOMICAL STRUCTURE, YIELD AND QUALITY OF SUGAR BEET (*BETA VULGARIS* L.)

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Abstract

A field trial using sugar beet (*Beta vulgaris* L.; *cv.*, SV-1697) was conducted at Agricultural Experimental Station of Desert Research Centre, Ras Sidr province, (latitude of $29^{o}60'28''$ N latitude and $32^{o}68'96''$ E longitude), South Sinai Governorate, Egypt during winter season of 2018/19 to study the response of sugar beet crop productivity under three magnetic brackish irrigation water treatments[i) Brackish-water (BW), ii) Magnetic-BW_1; brackish water after magnetization through passing a three inch static-magnetic; 1.75mT; and iii) Magnetic-BW_2; brackish water after magnetization through passing a three inch static magnetic unit; 0.75mT]. Results show that irrigation sugar beet plants with magnetically treated brackish-water (M-BW_1 or M-BW_2) surpassed significantly irrigation with brackish water (BW) in some of vegetative growth parameters at age of 90 days after sowing (*i.e.*, plant height (cm), fresh root length (cm), leaves number plant^{-1}, leaves dry weight (g plant^{-1}), leaf area (dm^2 plant^{-1}) and total chlorophyll (SPAD). As an average of both magnetically treated brackish-water, the increases in above mentioned vegetative growth parameters ranged between 4.80–27.75%. Similar trends were recorded in anatomical characters of sugar beet leaves where treatment with magnetically treated brackish-water increases the thickness of both mid vein and lamina due to the increase in thickness of mesophyll tissue as well as in the dimension of the main mid vein bundle by 5.23 to 25.25%. Also, macro (N, P, K, Mg) and micro (Fe, Cu, Zn) elements increased by irrigation with MBW. Revers trends were observed in best indicators for alleviation salinity stress (*i.e.*, Na, Cl and proline), where decrease under M-BW by 5.24, 6.25 and 7.23%, respectively compared to BW. Also, both magnetic treatments M-BW_1 and M-BW_2 significantly increased root length, diameter, weight, sucrose%, extractable sugar%, root and sugar yields (ton fed^{-1}). Root contents of impurities (±-amino N, Na and K) and Sugars lost to molasses percentage were significantly influenced by magnetically treated water. Under the conditions of this experiment, the results suggested that application of irrigation with M-BW_1 or M-BW_2 on sugar beet crop could be recommended to produce the best quality, highest root and sugar yields/fad.

Key words: Sugar beet, magnetic brackish-water, yield and quality, anatomical structure, proline.

Introduction

In Egypt, sugar beet cultivation (*Beta vulgaris* L.) came in the second order in sugar crops with cultivated area 260 thousand hectares and average production is approximately 47.1 tons/hectare (S.C.C. statistics, 2020). The cultivation of sugar beet is an important place in the rotation of Egyptian crops, either in fertile soils or in poor, salty, alkaline and calcareous soils. About 74% of our internal sugar needs are produced locally from sugar beet and sugarcane, while the rest (%26) is imported from foreign countries (S.C.C. statistics, 2020). Worldwide, salinity is a major and hazard problem especially in arid and semi-arid regions and affects crop production. The

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reasons for salinity are due to salt accumulation, which makes agricultural areas an unfavorable environment and limits the growth and production of plants and this condition leads to the so-called salt toxicity in plants not tolerated, or due to the decrease in the supply of good quality water for irrigation and farmers is forced to use underground water (Mostafazadeh-Fard, *et al.*, 2009; Mohamed *et al.*, 2015), since salinity of the soil increases the accumulation of salts by reducing the osmotic potential of soil water. This, in turn, lead to a decrease in pulp absorption water and this in turn leads to an imbalance in the division and cell elongation, which in turn affects biochemical reactions in plants as a result of the serious deterioration of the physical and chemical properties of the soil (Loveland, *et al.*, 1987). Therefore, new technologies are needed to reduce the rate of salt accumulation in the root zone of salt-sensitive or moderate agricultural crops in order to preserve the quantity and quality of water to avoid risks to the supply of water for future agriculture. Magnetic water technology is one of the most important strategies to reduce salt accumulation in agricultural soils, economically and safely to improve soil and water properties, which is reflected in the improvement of crop productivity (Hilal and Hilal, 2000; Hozayn and Abeer 2019; Hozayn *et al.*, 2019a & b & c; 2020). The magnetic effect transforms the large body of water into smaller molecules, facilitating water and nutrients for plants (Zhou *et al.*, 2011). Several studies in several countries, indicate that the magnetic treatment of irrigation water offers many benefits in agriculture, such as the improvement of germination, growth, production, early maturity of crops, reduction of plant diseases and salt stress, better crop quality, higher fertilizer efficiency and lower cost for agricultural operations (*i.e.*, Maheshwari and Grewal 2009; Babu 2010; Yusuf and Ugonila 2015; Ben Hassen *et al.*, 2020) and it seems that the effect of magnetically treated water depends on the species of plants, the length of the path in the magnetic field and the speed of the water flow (Gabrielli, *et al.*, 2001). Under Egyptian conditions, Hozayn, *et al.*, (2013; 2015a & b; 2016a & b and 2017) reported that irrigation with magnetized water has been shown to improve the growth, metabolism, quality and yield of proven crops (*i.e.*, wheat, barley, corn, beans, lentils, chickpeas, ground nuts and mango, sunflowers, canola, flax, sugar beet and potatoes). Similar trends were reported under salinity stresses of irrigation water and/or soil on wheat, barley and sunflower and sugar beet crops (Hozayn *et al.*, 2017; 2019a & b & c; 2020).

The current work aims to reduce the effect of salinity stress on productivity sugar beet (*Beta vulgaris* L.) using magnetized water technology under conditions of South Sinai region.

Materials and Methods

A field trial using sugar beet (*cv.*, SV-1697) under three irrigation water treatments (i) Brackish-water (BW), ii) Magnetic-BW_1; brackish water after magnetization through passing a three inch static-magnetic; 1.75mT; and iii) Magnetic-BW_2; brackish water after magnetization through passing a three inch static magnetic unit; 0.75mT] was conducted at Agricultural Experimental Station of Desert Research Centre, Ras Sidr province, (latitude of 29°60'28'' N; longitude of and 32°68'96''), South Sinai Governorate, Egypt during winter season of 2018/19 season. The treatments were tripled and laid out in Randomized Complete Blocks Design (RCBD) under drip irrigations system. The soil of site experiments and irrigation water were analyzed according to Chapman and Pratt, (1978; table 1). Table 1 reveal that soil of the experimental site was sandy loam, saline and poor in NPK and organic matter. Also, irrigation water was saline (table 1; Hozayn *et al.*, 2017).

Cultivation method and layout of Experiment: The soil was ploughed twice, ridged at 0.50 meter apart and divided into plots with area 45 m^2 and the area of

Table 1: The main chemical and physical properties of the experimental soil site and chemical composition of irrigation water.

Parameter	Soil depth (cm)		Irrigation water
	0-30	30-60	
pH	7.66	7.00	8.60
EC ($dS^{-1}m^2$)	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 class	Sandy loam	Sandy loam	..
Soil chemical properties:			
Soluble cations (meq/L)			
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	00.08	00.14
*SAR	10.18	12.80	8.17
Soluble anions (meq/L)			
CO_3^{-2}	0.00	0.00	0.00
HCO_3^{-}	3.44	2.00	4.50
SO_4^{-2}	58.93	65.20	29.23
Cl^{-}	64.14	51.50	48.94

*SAR=Na/SQRT(Ca^{+2} + Mg^{+2})/2

experimental unit was 15m^2. During seed preparation, 200 kg/fed calcium superphosphate (15.5% P_2O_5) was applied. Two-three seeds of tested sugar beet cultivar (*cv.*, SV-1697; obtained from Sugar Beet Research Institute, Agriculture Research Centre, Giza, Egypt) was sown manually in hills spaced 20 cm apart on one side of ridge at third week of October, 2018. Drip irrigation took place immediately after sowing and as plants needed during the period of experiment. Thinning was done at four leaf stage (after 35 days from sowing) to ensure one plant/hill. Nitrogen fertilizer as ammonium nitrate 33.5% N was applied at the rate of 150 kg/feddan in four equal portions; the first was applied after thinning, while the other three doses were given thereafter at 15-day intervals. Potassium fertilizer (as potassium sulfate 48% K_2O) was applied at the rate of 24 kg K_2O/feddan split into two doses, which were given after thinning and 15 days later, respectively. Other agricultural practices required for growing sugar beet were carried out as usual. Layout and design of experiment was shown in Fig. 1.

Data recorded

Growth characters: At age of 90 days, five plants were randomly taken from each plot to record plant and root length (cm), leaves (no plant^{-1}), leaves dry weight (g plant^{-1}), Leaf area (LA; dm^2 plant^{-1}).

Anatomical studies: A microscopically study was carried out to investigate the anatomical structure of the middle part of sugar beet leaf at the age of 90 days. All the specimens were fixed in F.A.A. solution (10 ml formalin, 5 ml glacial acetic acid, 50 ml ethyl alcohol 95%, 35ml distilled water). The materials were left in the fluid for three days, after which they were washed in 50% ethyl alcohol and gradually dehydrated in a normal butyl alcohol series before being embedded in paraffin wax (melting point 52-54°C). Transverse sections, 20μ thick, were cut using a rotary microtome and stained with double crystal violet/erythrosine combination and mounted in Canada balsam (Nassar and El-Sahhar, 1998). Examination and photomicrographs were taken using a Reichert Microstar IV microscope and digital camera (Cannon Power Shot G12) at Botany Department, Faculty of Agriculture, Cairo University, Egypt. Average of readings from 4 slides/ treatment was calculated.

Chemical analysis in leaves at 90 days after sowing (DAS): Some biochemical aspects were determined including macro elements (N, K, Mg, Ca and Na) and micro elements (Fe, Mn, Zn and Cu) content in dry leaves at 90 DAS were assayed according to Cottenie *et al.*, (1982). Total N concentration was determined as described in (A.O.A.C., 1995). K, Ca, Na were measured using flame photometer. While, estimation of Mg, Fe, Mn, Zn and Cu contents were determined using the Atomic absorption spectrophotometer (Perkin Elemer 100-B). Proline content in dry leaves was extracted and calculated according to Bates *et al.*, (1973). Total Chlorophyll in shoot was determined using SPAD Chlorophyll meter (Konica Minolta Optics, 2012).

Yield, yields components and quality: At harvest, a random sample of ten guarded roots of each plot was taken to determine yield components parameters (*i.e.* root length, diameter and weight). Plants in 20 m^2 form four lines and 5.0 m in length from each plot were collected and cleaned, therefore roots were separated and weighted in kilograms and converted to estimate root yield (ton fad^{-1}). Sugar yield (ton fad^{-1}) was calculated by multiplying

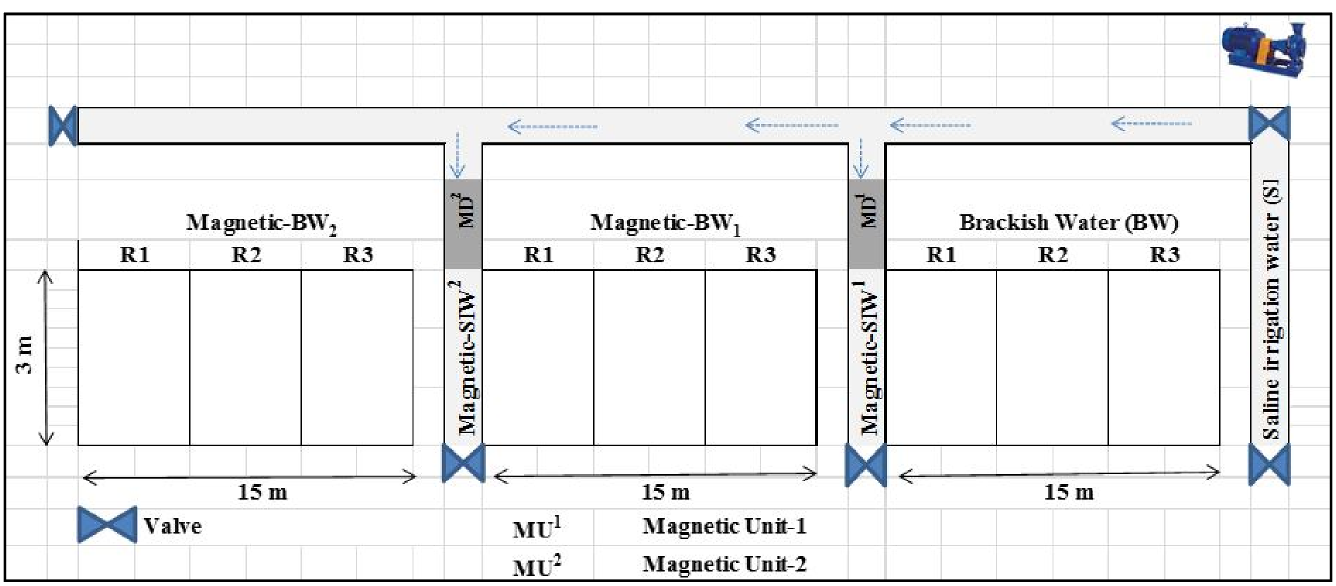

Fig. 1: Layout and design of experiment.

root yield by extractable sugar percentage. Plant samples were then sent to the laboratory of quality analyses at Fayoum Sugar Company to determine the following quality characteristics: Sucrose percentage which was estimated in fresh samples of sugar beet root using "Saccharometer" according to the method described by A.O.A.C. (2005). Impurities in terms of ±-amino N, Na and K percentages (meq/100 g beet) according to A.O.A.C. (2005). Purity percentage was calculated according to the following equation, described by Devillers (1988): Purity% = 99.36 – [14.27 (Na + K + a-amino N)/ sucrose%]. Sugars lost to molasses percentage (SLM%) was calculated as described by Devillers (1988) using the following equation: SLM% = [0.14 (Na + K) + 0.25 (±-amino N) + 0.5]. Extractable sugar percentage (ES%) was calculated using the equation of Dexter, *et al.*, (1967) as follows: ES% = [sucrose% – (sugar lost to molasses% + 0.6)].

Statistical analysis: Data were statistically analyzed using MSTAT-C computer package (Freed, *et al.*, 1989). The least significant difference ($LSD_{5\%}$) test was used to compare among the means of treatments.

Results and Discussion

Growth character at 90 DAS

Data in table 2 reveal that irrigation sugar beet plants with magnetically treated brackish-water (M-BW_1orM-BW_2) surpassed significantly irrigation with brackish water treatment (BW) in all tested vegetative growth parameters at age of 90days. As an average of both magnetically brackish-water treatments, the percent of improvement over control reached 20.61, 18.97, 18.09, 27.75 and 12.35% in plant height (cm), length of fresh root (cm), leaves (no $plant^{-1}$), leaves dry weight (g $plant^{-1}$), LA (dm^2 $plant^{-1}$), respectively. These results confirmed previous studies under normal and salinity stress conditions (Hozayn *et al.*, 2013; 2017; 2019a & b & c; 2020). Many studies also showed that magnetic treatment of water has been reported to change some physical and chemical properties of water, mainly hydrogen boding, polarity, conductivity, pH and solubility of salts (Amiri and Dadkhah, 2006; Ozeki and Otsuka, 2006). These changes in water properties may be capable of positive effecting the growth of plants.

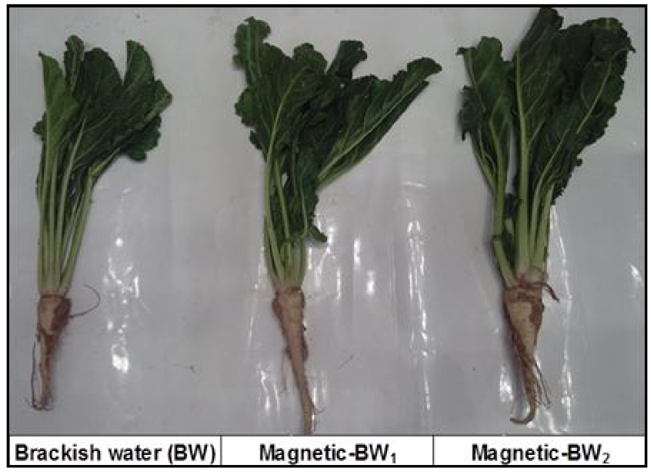

Fig. 2: Comparison among magneticbrackish-water treatments on vegetative growth of sugar beet at 90 days after sowing (DAS).

Table 3: Comparison among magnetic-brackish water treatments on histological features on sugar beet leaf at 90 days after sowing (DAS).

Treatment Character		Brackish-water (BW)	Mag-netic -(BW_1)	Mag-netic -(BW_2)
Mid vein thickness		2060	2155	2570
Lamina thickness		680	875	960
Dimen-sions of the middle vascular bundle of mid vein	Length	490	540	650
	Width	345	425	530
	Xylem	370	410	450
	Phloem	135	160	175

Anatomical studies

Leaf anatomy: Microscopically, measurements of certain histological features in transverse sections through the middle part of the sugar beet leaf *cv.* SV-1697 as affected by magnetic water (M-BW_1 and M-BW_2) compared with brackish water (BW). It is recognized from table 3 and Fig. 2 that treatment with magnetic water at saline condition gave the best results of sugar beet *cv.* SV-1697 related to leaf structure as compared to the plants irrigated with brackish water. The increase in mid vein and lamina thickness were 4.6 and 28.7% for MBW_1, whereas in MBW_2 increased by 24.8 and 41.2% over control. The promoted effect of magnetic water on leaf thickness may be due to an increase in thickness of mesophyll tissue. In the present study, the dimensions of vascular

Table 2: Comparison among magnetic brackish-water treatments on vegetative growth of sugar beet at 90 days after sowing (DAS).

Treatment Character	Brackish-water (BW)	Magnetic -(BW_1)	Magnetic -(BW_2)	F-Sign.	$LSD_{5\%}$
Plant height (cm)	37.00	43.25	46.00	**	2.39
Root length (cm)	14.50	17.00	17.50	**	1.58
Leaves (no $plant^{-1}$)	11.75	13.75	14.00	ns	ns
Leaves dry weight$plant^{-1}$)	52.25	63.50	70.00	**	3.15
Leaf area(dm^2 $plant^{-1}$)	58.93	65.98	66.43	ns	ns

**:Significant at $P< 0.01$; ns: non-significant.

bundle in MBW_1 increased in length by 10.2% and width by 23.2%. On the other hand, the increase in length and width in MBW_2 were 32.7 and 53.6%, respectively. Likewise, xylem increased by 10.8 and 21.6% over control for MBW_1 and MBW_2, respectively. Also, phloem tissue increased by 18.5% in MBW_1, while increased by 29.6% in MBW_2. Majd and Farzpour-machiani (2013) found that leaf sections showed more compressed palisade parenchyma than control. Also, noticed that shoot diameter, number of vascular bundle and volume of cells of cortical parenchyma increased by magnetic field increasing. Hozayn *et al*., (2016a) mentioned that potato leaf treated by magnetic water was thicker in mid vein and lamina due to the increase in thickness of palisade and spongy tissues. Likewise, mid vein bundle was increased in size.

Chemical analysis in sugar beet leaves at 90 DAS

Data in table 4 showed that MTW had a significant effect difference on leave contents of macro and micro-elements among magnetic irrigation brackish-water treatments at 90 days from sowing, where irrigation sugar beet plants with magnetic-brackish water ($M\text{-}BW_1$ or $M\text{-}BW_2$) improved leave contents of N, K, Mg, Zn and Cu. As an average of both magnetically treated brackish water, the percentage of improving reached 13.25, 6.69, 59.06, 11.03 and 19.33% in the above mentioned elements, respectively compared to irrigation with brackish-water. Reverse trends were observed in leave contents of Na, Ca, Fe and Mn where were decreased by 57.14, 9.38, 33.24 and 9.91% due to applications of magnetically treated brackish water treatments (average of $M\text{-}BW_1$ and $M\text{-}BW_2$; table 3) as compared to irrigation with brackish water. These results can be attributed for Chlorophyll contents have a basic importance for plant productivity, the most important issue for farmers. Low chlorophyll content below 2 mg dm^{-2} of leaf surface causes insufficient absorption of the sun light and low plant

Table 4: Comparison among magnetic-brackish water treatments on some macro and micro- nutrients in sugar beet leaves at 90 days after sowing (DAS).

Treatment Character		Brackish -water(BW)	Magnetic -($M\text{-}BW_1$)	Magnetic -($M\text{-}BW_2$)	F-Sign.	$LSD_{5\%}$
Macro-nutrientsin leaves (%)	N	1.90	2.12	2.18	*	0.17
	K	2.52	2.62	2.75	ns	ns
	Mg	1.47	2.32	2.36	**	0.18
	Na	1.40	0.65	0.55	**	0.35
	Ca	1.60	1.50	1.40	**	0.07
Micro-nutrientsin leaves (ppm)	Fe	178.00	114.67	123.00	**	10.94
	Mn	116.00	107.00	102.00	**	5.07
	Zn	133.00	145.00	150.33	**	5.12
	Cu	3.00	3.50	3.66	**	0.18
Total chlorophyll (SPAD)		128.31	134.11	134.83	ns	ns
Proline (ppm)		281.25	272.25	264.00	**	4.77

*: Significant at $P< 0.05$; **: Significant at $P< 0.01$; ns: non-significant.

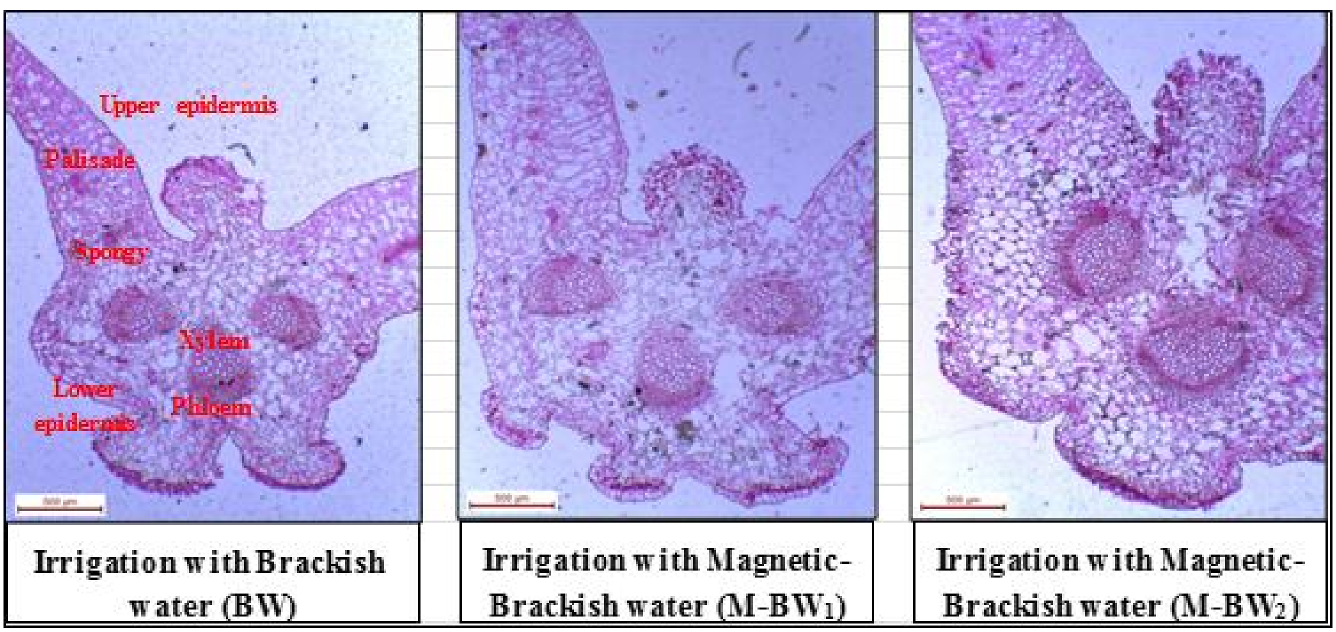

Fig. 3: Transverse sections through the middle part of sugar beet leaf cv. SV-1697 aged 90 days as affected by magnetic water. (X 40).

Table 5: Comparison among magnetic brackish-water treatments onyield,yield components and quality of sugar beet at harvest.

Treatment Character		Brackish -water(BW)	Magnetic -(BW_1)	Magnetic -(BW_2)	F- Sign.	$LSD_{5\%}$
Yield and yield compo-nents	Root length (cm)	26.75	29.50	30.50	*	2.54
	Root diameter (cm)	9.27	10.38	10.75	**	0.69
	Root weight (kg)	0.67	0.79	0.81	**	0.04
	Root yield (ton fad^{-1})	10.13	11.88	12.11	**	0.04
	Sugar yield (ton fad^{-1})	1.41	1.78	1.85	**	0.43
Quality parameters (mmol/100 fresh root)	Sucrose(%)	16.56	17.35	17.67	**	0.23
	Na	2.40	2.13	2.10	**	0.07
	K	3.71	3.20	3.22	**	0.02
	α-Amino nitrogen	2.42	2.04	1.97	**	0.16
	Purity (%)	82.53	83.25	83.10	ns	0.64
	Sugars lost to molasses(%)	1.96	1.76	1.74	**	0.04
	Extractable sugar (%)	14.00	14.99	15.33	**	0.28

*: Significant at $P< 0.05$; **: Significant at $P< 0.01$; ns: non-significant.

productivity, About 3 mg of chlorophyll of leaf surface ensures the optimal (95-97%) consumption of sun light absorbed by plants (Rochalska, 2005). The same results were obtained by Atak, *et al.,* (2007) who found an increase in chlorophyll content specifically appeared after exposure to a magnetic field for a short time table 4. Also, table 4 shows that irrigation sugar beet plants with magnetically treated brackish-water (M-BW_1 or M-BW_2) treatments reduced significantly proline concentration in sugar beet leaves at 90 DAS by 3.20 and 6.13%, respectively compared to irrigation with brackish water treatment. The studies on the effect of magnetized water technology on nutrients, showed that magnetic treatment of water has been reported to change some physical and chemical properties of water, mainly hydrogen boding, polarity, conductivity, pH and solubility of salts (Amiri and Dadkhah, 2006; Ozeki and Otsuka, 2006). These changes in water properties may be capable of positive effecting the nutrients contents of organs plants of plants.

Yield, yields components and quality

Data in table 5 showed that the irrigation with magnetically treated brackish-water (M-BW_1 or M-BW_2) treatments surpassed significantly irrigation with brackish-water treatment (BW) in fresh root parameters at harvest. As an average of both magnetically brackish-water treatments, the percent of improvement over control reached 12.15, 13.97, 19.40 and 18.41 and 28.72% in root length, diameter, weight, root and sugar yield (ton fad^{-1}), respectively compared to irrigation with brackish (BW) treatment. Similar trends were recorded in sucrose and extractable sugar percentages, where the percent of improvement over control reached 5.74 and 8.29% in the above-mentioned parameters, respectively, while the Na, K, α-amino nitrogen and sugars lost to molasses percentage as they were decreased by 11.88, 13.48, 17.15 and 10.71 compared to irrigation with brackish (BW) treatment. At the same time purity percentage was insignificantly affected by the water treatments. Sugar beet root parameters (*i.e.*, length, diameter and weight) are considered the main indicators for yields. The results obtained by different authors confirmed the beneficial effect of low frequency of magnetic field on root and leave growth of sugar beet (Vasilevski, 2003 and Rochalska, *et al.,* 2008, Hozayn *et al.,* 2013).

Conclusion

Under conditions of this experiment, the results suggested that application of irrigation with M-BW_1 or M-BW_2 on sugar beet crop can be recommended to reduce the salinity stress, addition to produce the best quality, highest root and sugar yields/fad.

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