Effect of Magnetic Brackish-Water Treatments on Morphology, Anatomy and Yield Productivity of Wheat (*Triticum aestivum* L.) under Salinity Stress Conditions

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ABSTRACT

This study included two factors: 1) three irrigation water treatments i) Brackish-water (BW), ii) Magnetic-BW_1; brackish water after magnetization through passing a three inch static-magnetic unit produced by Delta Water Company and iii) Magnetic-BW_2; brackish water after magnetization through passing a three inch static magnetic unit produced by Magnetic-Technologies Company) and three wheat varieties (Sakha-94, Maser-2 and Gemiza-11). The three irrigation water treatments and the three tested varieties were laid out in split-plot design with three replicates and allocated in the main and sub-plots, respectively under gated pipe irrigations system. The experiments designed at Agricultural Experimental Station of Desert Research Centre, Ras Sidr province, South Sinai Governorate, Egypt. The results indicated that irrigation tested wheat varieties with magnetically treated BW_1 or magnetically treated BW_2 treatments surpassed irrigation with brackish water in all tested vegetative growth parameters at 75 DAS (i.e., plant height (cm), fresh and dry weight of wheat shoot (kg m^2), water contents (%), Flag leaf area (cm^2 $plant^{-1}$) as well as shoot contents of N, Mg, Ca, Fe and Cu. While revers trends were recorded in Na, Mn, Zn and proline. Results also, recorded that micro-morphological characters as number of cells and thickness of layer in addition to the diameter of vascular bundled especially the xylem vessels were compatible with vegetative growth parameters. The yield crop which is the most important was increased with irrigation by magnetic water. As an average of magnetically BW treatments, the percent of improvement reached to 19.24, 33.97 and 26.99% in grains, straw and biological yield (ton fed^{-1}), respectively compared to irrigation with brackish water. The clear improvement in productivity of tested wheat verities under magnetically treated brackish irrigation water may be due to the reduction of irrigation and/or soil salinity stress as a result of displacement of salts away from the root zone spread, lack of sodium exchange in the soil, availability of most fertilizer elements; increased cations exchange capacity and improved soil aggregation. It be concluded that, application of this technology could be play a vital role for improving wheat productivity when sowing under these conditions.

Kew words: Magnetic brackish-water, salinity stress, wheat productivity, morphology, anatomy.

INTRODUCTION

Worldwide, approximately twenty percent of the world's cultivated land and about 50% of all irrigated lands are affected by salinity (Zhu, 2002). Salinity shares the drought to become the two major environmental factors determining plant productivity and plant distribution. Soil salinity problem has been aggravated by agricultural practices such as irrigation with brackish water. Under Egyptian condition especially in Sinai region which depended mainly on well water, the irrational use of well water leads to a low level and quality of irrigation water through increased its salinization. Therefore, agricultural scientist takes into consideration not only common agricultural practices but un-common tools *i.e.*, magnetic field. Application of magnetic technology in agriculture is considered one of non-conventional technology, safe healthy, economic, environmentally and promising to improve soil and water properties, which is reflected for improving, growth, yield and water productivity (Hozayn & Ahmed 2019 and Hozayn *et a.l* 2019a&b). Application of this technology are being applied either by the magnetization of water through passing in static magnetic unites or expose of seeds for magnetic field. Many researchers have also studied the positive effects on plants with seeds subjected to electric, magnetic or electromagnetic field (*i.e.*, Turker *et al.*; 2007, Ozge*et al.*; 2008, Maheshwari and Grewal; 2010 and Moussa; 2011).

Anatomical characteristics are indicators of plant adaptation to environmental stresses (Wahid, 2003 and Hameed *et al.*, 2010). For example, in saline-waterlogged conditions, formation of aerenchymatous

DOI: 10.21608/ASEJAIQJSAE.2019.63578
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Received October 03, 2019, Accepted November 30, 2019

nodal roots has been reported to improve Na^+ exclusion and hence salt tolerance in wheat (*Triticum* spp.; Saqib*et al*., 2005). The larger size of epidermal and bulliform cells were found to be developed in plants subjected to drought and saline stresses (Nawazish *et al*., 2006 and Hameed *et al*., 2009). Under high salinity, formation of parenchyma in leaf sheath, increased vascular bundle area, metaxylem area and phloem area, highly developed bulliform cells on leaves and increased sclerification in root and leaf have been reported (Hameed *et al*., 2009). Structural modifications, specifically for combating environmental stresses like salinity and drought, considerably help conserve water, that is, either water loss is minimized or additional water stored.

In Egypt previous studies under non-saline or saline condition in Ismailia, South Sinai and Nubaria regions (Hozayn e*t al.*, 2015a&b, 2016, 2017 and 2019) revealed that, wheat, barley, faba bean, lentil, chickpea, sunflower, canola and ground nut, flax, sugar beet and potato irrigated with magnetized-water improved growth, yield and quality compared untreated treatment. In abroad also, clear increasing (10.6-144.8%) in economic yield of many crops (i.e., cereal, wheat, rice, soybean, broad bean, sugar beet, sunflower, pepper and pea) were recorded under magnetic field treatments in macro experiments (i.e., Vasilevski 2003; Aladjadjiyan, 2007; Vashisth and Nagalajan, 2010; Surendran *et al*., 2016; Vladimir 2017; Razmkhaha *et al*., 2018). They recorded that, the increasing in yield were accompanied by improvement in quality parameters i.e., protein, oil, sugar, and carbohydrates percentage. Generally, change in some physical and chemical properties of water and soil may be reflected in the positive effects on growth, yield and water productivity under magnetic water treatments (Maheshwari and Grewal 2009; Surendran *et al*., 2016; Vladimir 2017; Razmkhaha *et al*., 2018 and Ben omer *et al*., 2018).

In Egypt there is a big gap (40%) between wheat production and consumption due to increase in population and decrease the agricultural land due to desertification, salinization and water deficiency which considered a big problem. This experiment is designed to evaluate the effect of magnetic brackish water treatments on the growth of three wheat varieties grown under conditions of the saline soil and irrigation water in South Sinai region.

MATERIALS AND METHODS

A field trial using wheat (*Triticum aestivum* L.) varieties; Sakha-94, Maser-2 and Gemiza-11) under three irrigation water treatments: i) Brackish-water (BW), ii) Magnetic-BW_1; brackish water after magnetization through passing a three inch static-magnetic unit produced by Delta Water Company iii) Magnetic-BW_2; brackish water after magnetization through passing a three inch static magnetic unit produced by Magnetic-Technologies Company) was conducted at Agricultural Experimental Station of Desert Research Centre, Ras Sidr province, South Sinai Governorate, Egypt during winter season of 2017/18. The three irrigation water treatments and the three tested varieties were laid out in split-plot design with three replications and allocated in the main and sub-plots, respectively under gated pipe irrigations system. The experimental area is located on the Gulf of Suez and the Red Sea coast (29º60'28" N latitude and 32º68'96" E longitude). The soil of experimental site and irrigation water were analyzed according to Chapman and Pratt, (1978) and the results are shown in Table (1). Table 1 reveals that soil of the experimental site was sandy loam, saline and poor in available NPK and organic matter content and irrigation water as classified as saline (Hozayn *et al*., 2017).

Cultivation methods and layout of experiment:

The soil was ploughed twice, divided into main plots with area 60 m^2 (15 m width x 4 m length) and sub plots with area 20 m^2 (5m width x 4m length). During seed bed preparation, 150 Kg fed^{-1} calcium superphosphate (15.5% P_2O_5) was applied. Recommended rates of wheat grains (60 Kg fed^{-1}; Var., Sakha-94, Maser-2 and Gemiza-11) were sown by drilling manually in the rows at 20-cm apart at the second week of November, 2017. Gated pipe irrigation system took place immediately after sowing and as plants needed during the period of experiment. Nitrogen fertilizer as ammonium sulfate (20.60 N%) at the rate of 120 kg N fed^{-1} was added in four equal doses starting from 15 days after sowing till flowering, potassium fertilizer at the rate of 50 kg fed^{-1}as potassium sulfate (48% K_2O) was added after one month from sowing. Others recommended agricultural practices for sowing wheat was done according to leaflet Agriculture Research Centre under this province conditions. Experimental layout is shown in (Fig 1).

Data Recorded:

Growth parameters: After 75 days from sowing; plant height, fresh and oven dried weight of 0.50 x 0.50 m^2 plants from each treatment were determined. Water content was determined according to Henson *et al*., (1981) using the following formula: WC = 100×(fresh mass – dry mass)/fresh mass. Flag Leaf area was measured according to Quarrie and Jones equation; Leaf area = Length x Breadth x 0.75 (Chanda and Singh, 2002 and Aldesuquy *et al*., 2014)

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

Parameter	Soil depth (cm) 0-30	Soil depth (cm) 30-60	Irrigation water
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 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^{-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

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

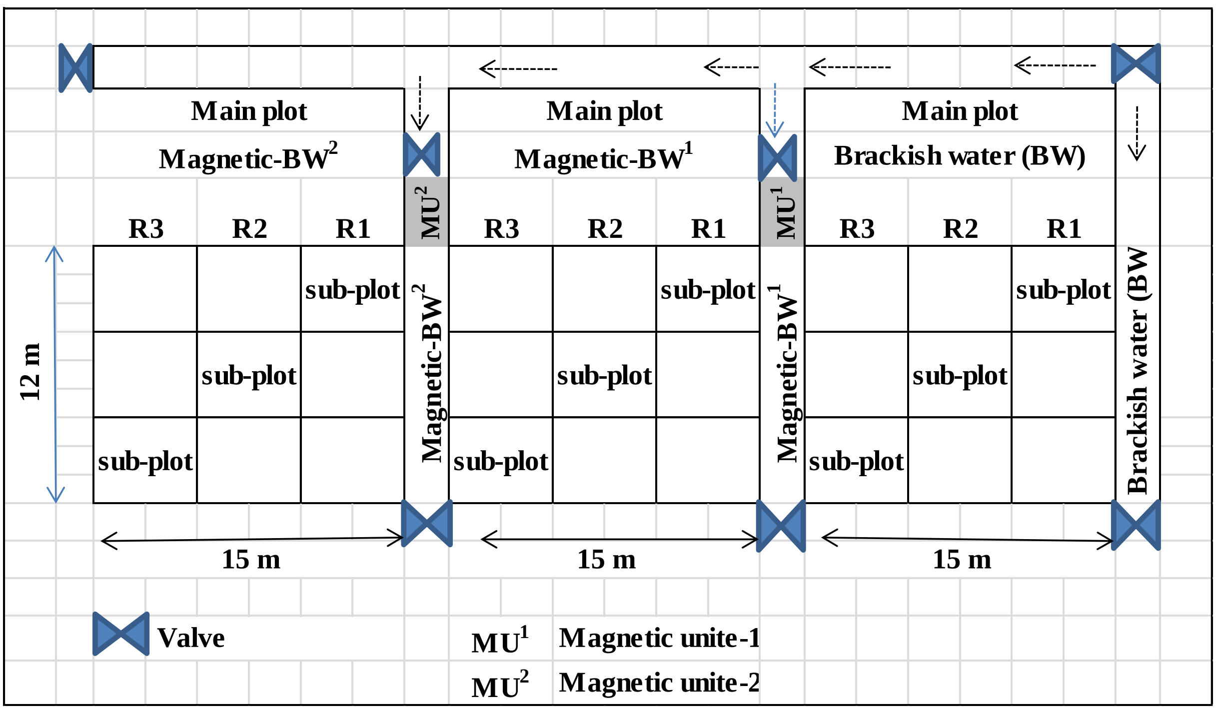


Fig. 1. Layout and design of the field experiment

Micro-morphological investigation: Specimens were taken at 75 DAS. Cross section of stem and lamina from the third node were preserved and fixed in formalin, ethyl alcohol, acetic acid mixture (8:1:1). Sections of stem and lamina were dehydrated and embedded in paraffin wax and was sectioned using rotary microtome at 10-15 µm, then were deparafinized and stained using safranine and light green and mounted with Canada Balsam according to the traditional methods of Johanson (1940). Metcalfe and Chalk (1950) were used to describe the anatomical features. Examination (three section for each) and photomicrographs were taken using a Reichert Microstar IV microscope and digital camera (Cannon Power Shot G12) at Plant Taxonomy Research Laboratory, Botany Department, Faculty of Science, Ain Shams University. The measurements of various cells and tissues were taken with ocular micrometer and exact values were computed with factor derived by comparing ocular and stage micrometer.

Chemical analysis of shoot at 75 DAS: Macro-nutrients, N, P, K, Mg, Ca, Na, and micro-nutrients Fe, Mn, Zn andCu concentrations were determined in the oven dried plant material of shoot at 75 DAS according to Chapman and Pratt (1978). Total N was determined based micro-Kjeldahl method. Potassium, calcium and sodium were determined using flame photometer (Genway) while Mg, Fe, Mn, Zn and Cu contents were determined using Atomic absorption spectrophotometer (Perkin Elemer 100-B). Proline content in dry leaves was extracted and calculated according to Bates *et al.* (1973).

Yield and yield components: At the harvest stage, one square meter from each plot was used to determine number of spikes/m^2as well as plant height, number of spikelets and grains per spike, length and weight of spike, grains weight of spike and 100–grains weight from randomly selected 20 tillers from each plot. The 4 square meter from each treatment was threshed manually to determine grains, straw and biological yield per 4 m^2 that was converted into ton per fed. Harvest index was calculated by dividing seed yield/biological and crop index was calculated by dividing seed yield/straw yield.

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.

RESULTS AND DISCUSSION

RERSULTS

Vegetative growth:

Significant variations among the tested three wheat varieties, magnetized water treatments and its interaction on growth parameters at 75 DAS, i.e., plant height (cm), fresh and dry matter of tillers shoot (kg m^{-1}) and flag leaf area (cm^2 $plant^{-1}$) are recorded in Table (2). Regarding irrigation water treatments, the data reveals that, irrigation with magnetically treated brackish-water$_1$ (M-BW_1) or magnetically treated brackish-water$_2$ (M-BW_2) treatments surpassed irrigation with brackish water (BW) in all tested growth parameters. As an average of both magnetically brackish-water treatments, the percent of improvement compared to irrigation with brackish water reached 20.80, 40.91, 43.02 and 23.49% for growth parameters, respectively. Also, significant differences were recorded among wheat varieties where Gemiza-11 produced the highest values for the above-mentioned growth characters followed by Masr-2 and Sakha-94, respectively. As well as, it is that, irrigation with M-BW_1 or M-BW_2 caused positive effects on the growth of the three wheat varieties compared to irrigation with brackish water. Gemiza-11 came in the first order by increasing reached 29.75, 47.02, 52.57 and 30.24% in plant height (cm), fresh and dry matter of tillers shoot (kg m^{-1}) and flag leaf area ($cm^2 plant^{-1}$) followed by Masr-2 by 16.29, 46.45, 45.00 and 29.15% and Shakha-94 by 15.60, 27.10, 30.27 and 28.40%, respectively as on average increasing for both magnetically brackish-water treatments (M-BW_1 and M-BW_2) compared to irrigation with brackish water (BW).

Anatomical Studies:

Regarding micro-morphological characters, the three wheat varieties showed the same anatomical background of terete stem outline, thin cuticle, radially elongated epidermis, scattered vascular bundles, and polyhedral parenchyma in pith region. Anatomical data including thickness of different cells and layers were calculated as shown in Table (3) and the major different aspects were illustrated in Plate (1). The data revealed that M-BW_1 or M-BW_2 has positive on most stem anatomical features effects of the tested three wheat varieties compared with brackish water (BW) treatment. The most anatomical characters (stem sections) are the increase of number of vascular bundles and the diameter of vessels. The epidermis thickness, cortex thickness, sclerenchyma thickness, parenchyma thickness and number of vascular bundles were increased in tested wheat varieties sakha-94 and Masr-2 as the results of irrigation by MBW_1 and MBW_2 than irrigation by BW. In Gemiza-11, the cortex thickness, sclerenchyma thickness,

Table 2. Plant height, fresh and dry mater of shoot (kg m^2 plant^{-1}), and flag leaf area (cm^2 plant^{-1}) at 75 DAS of the three wheat varieties under different magnetic brackish water treatments

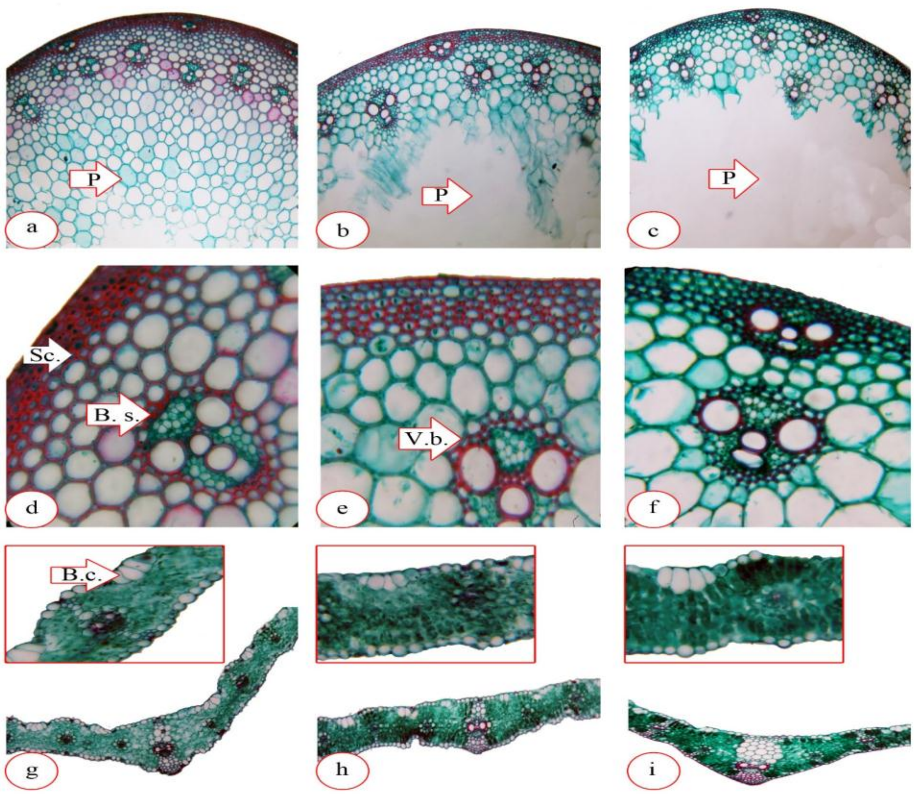
Treatment		Plant height (cm)	Tiller weight (kg/m^2)		Water content (%)	Flag leaf area (cm^2 plant^{-1})
Water	Variety		Fresh	Dry		
Brackish water (BW)	Sakha-94	50.00	2.76	0.53	80.52	20.97
	Masr-2	52.50	2.88	0.56	80.56	29.34
	Gemiza-11	56.30	3.19	0.60	81.20	33.12
Magnetic-BW$_1$ (M-BW$_1$)	Sakha-94	56.00	3.35	0.66	80.21	26.65
	Masr-2	61.20	4.30	0.84	80.47	41.93
	Gemiza-11	74.10	4.72	0.87	81.60	35.23
Magnetic-BW$_2$ (M-BW$_2$)	Sakha-94	59.60	3.66	0.73	80.13	27.20
	Masr-2	60.90	4.14	0.78	81.62	33.85
	Gemiza-11	72.00	4.65	0.95	78.83	41.19
F test		**	**	**	ns	***
$LSD_{5\%}$		5.48	0.10	0.08	ns	2.44
Water treatment	BW	52.93	2.94	0.56	80.76	27.81
	MBW$_1$	63.77	4.12	0.79	80.76	34.60
	MBW$_2$	64.17	4.15	0.82	80.20	34.08
F test		**	**	**	ns	*
$LSD_{5\%}$		1.98	0.09	0.12	ns	3.47
Variety	Sakha-94	55.20	3.26	0.64	80.29	24.94
	Masr-2	58.20	3.77	0.73	80.88	35.04
	Gemiza-11	67.47	4.19	0.80	80.54	36.51
F test		***	***	***	ns	***
$LSD_{5\%}$		3.16	0.06	0.05	ns	1.31
$CV_{\%}$		5.11	1.46	6.20	2.11	3.26

Table 3. Measurements (in microns) of certain anatomical characters in transverse sections through the stem of the three wheat varieties under different magnetic brackish-water treatments

Treatment	Sakha-94			Masr-2			Gemiza-11		
Stem anatomy character	**BW**	**MBW$_1$**	**MBW$_2$**	**BW**	**MBW$_1$**	**MBW$_2$**	**BW**	**MBW$_1$**	**MBW$_2$**
Stem diameter	50.50	59.00	63.50	47.00	48.50	53.50	54.00	61.00	55.00
Epidermis thickness	2.00	2.50	2.00	1.50	2.00	2.00	1.50	2.00	2.00
Cortex thickness	17.50	28.00	35.00	34.00	49.00	69.00	76.00	34.00	25.00
Sclerenchyma thickness	6.00	9.50	11.00	10.50	13.00	13.00	11.50	10.50	6.50
Parenchyma thickness	15.00	24.00	29.50	30.00	41.50	57.50	70.00	31.00	21.00
Vascular cylinder thickness	20.00	28.00	30.00	29.00	30.00	34.00	22.00	29.00	22.00
Bundle sheath fiber	**1 layer inc.**	**1 layer inc.**	**1 layer inc.**	**1 layer inc.**	**1 layer inc.**	**1 layer inc.**	**2 layers com.**	**2 layers com.**	**2 layers com.**
Average vessel diameter	6.00	7.00	9.00	7.00	8.00	9.00	6.00	8.00	8.00
No. of vascular bundles	48-50	57-60	59-60	30-31	34-38	40-41	50-52	40-44	35-38
Pith width	34.50	33.00	41.50	28.00	11.00	6.00	4.50	37.50	37.50

Table 4. Measurements (in microns) of certain anatomical characters in transverse sections through the lamina of the three wheat varieties under different magnetic brackish-water treatments

Treatment	Sakha-94			Masr-2			Gemiza-11		
Lamina anatomy character	**BW**	**MBW_1**	**MBW_2**	**BW**	**MBW_1**	**MBW_2**	**BW**	**MBW_1**	**MBW_2**
Midrib thickness	28.00	18.00	30.00	19.00	12.00	23.00	18.00	13.00	23.00
Wing thickness	13.00	10.00	15.00	13.00	8.00	11.00	9.00	8.00	11.00
Bulliform cells	9 x 6	5 x 5	12 x 9	8 x 4	8 x 6	6 x 7	8 x 5	5 x 5	9 x 6
Mesophyll thickness	30.00	26.00	34.00	32.00	29.00	30.00	24.00	21.00	29.00
Adaxial sclerenchyma thickness	7.00	3.00	3.00	3.00	3.00	5.00	3.00	2.00	4.00
Abaxial sclerenchyma thickness	20.00	14.00	18.00	15.00	4.00	19.00	12.00	8.00	14.00
Parenchyma thickness	40.00	18.00	45.00	16.00	10.00	15.00	14.00	8.00	25.00
Midvein vascular bundle	20.00	16.00	24.00	16.00	12.00	19.00	14.00	18.00	21.00
Adaxial trichomes (papillae)	+	+	+	+	+ few	++	+	+ few	+ +



The major anatomical aspects of *Triticum* sp. with relation to using magnetic water
(a,d & g nontreated plants - b, c, e, f, h & i treated plants)
figs. a-f; stem anatomical feature
figs. g-i; lamina anatomical features
Legends:B. c.; Bulliform cells, B.S.; Bundle sheath fiber, Sc.; Scelerenchyma, P.; Pith, V.b.; Vascular bundle.

Plate 1.The major anatomical aspects of wheat (cv. Gemiza-11) stem and lamina under different magnetic brackish-water treatments

parenchyma thickness and number of vascular bundles were decreased with using M-BW_1 and M-BW_2. The lamina anatomical features were increased with using M-BW_1 and M-BW_2 (Table 4 and Plate 1). The most anatomical characters are the well-developed bulliform cells, extensive sclerification in the leaf sheath in addition to the thick cuticle.

Macro and Micro-nutrients and Proline Contents in Shoot:

Table 5 showed that the tested wheat verities (Sakha-94, Masr-2 ad Gemiaza-11) contained more values of macro and micro-nutrients in shoot at 75 DAS, except Na, Mn and Zn, under irrigation with M-BW_1 or M-BW_2 than irrigation with Brackish-water (BW). Gemiaza-11 variety came in the first order for all recorded nutrients elements followed by Masr-2 and Sakha-94, respectively. Generally, as an average of both magnetically brackish-water treatments and the three tested wheat varieties, the percent of improvement over control reached to 15.11, 15.42, 14.93, 17.65, 29.55 and 10.15% in shoot contents of N, K, Mg, Ca, Fe and Cu, respectively compared to BW treatment. Table 5 also reveals that, revers trends were reported in shoot contents of Na, Mn, Zn and proline where it were reduced by 51.12, 18.52, 25.32 and 38.67%; respectively.

Wheat Yield and its Components:

At harvest date, Tables (6 and 7) showed significant variation among the tested three wheat varieties, magnetized brackish-water treatments and its interaction on wheat yield and its components. Regarding irrigation water treatments, data showed that, irrigation with magnetically treated brackish-$water_1$ (M-BW_1) or magnetically treated brackish-$water_2$ (M-BW_2) surpassed irrigation with brackish water (BW) in all tested parameters. As an average of both magnetically brackish-water treatments, the percent of improvement reached 10.83 in plant height, 29.80% in number of spikes/m^2, 12.29% in spike length, 23.65% in spike weight, 12.87% in grains weight spike and 10.94% in 100–grains weight (Table 6). Similar trends were observed in grains, straw and biological yields per feddan (Table 7) where the increases reached 19.24, 33.97 and 26.99% in grains, straw and biological yield, respectively. Also, significant differences were recorded among wheat varieties in yield and its wheat components where Gemiza-11 gave the highest values for above mentioned characters followed by Masr-2 and Sakha-94,

Table 5. Macro and Micro-nutrients and proline contents in shoot at 75 DAS of the three wheat varieties under different magnetic brackish water treatments

Treatment		Macro-nutrients in shoot (%)					Micro-nutrients in shoot (ppm)				Proline (ppm)
Water	Variety	N	K	Mg	Na	Ca	Fe	Mn	Zn	Cu	
Brackish water (BW)	Sakha-94	1.20	2.07	0.19	0.85	1.30	125.00	43.39	148.00	4.50	2360
	Masr-2	1.24	2.15	0.25	0.95	1.40	143.00	45.50	139.33	4.50	500
	Gemiza-11	1.30	2.12	0.22	0.89	1.35	146.00	39.80	152.00	4.53	1480
Magnetic-BW_1 (M-BW_1)	Sakha-94	1.38	2.27	0.22	0.40	1.51	142.00	38.25	118.00	5.27	1260
	Masr-2	1.43	2.46	0.26	0.55	1.75	170.00	37.97	108.00	4.47	420
	Gemiza-11	1.40	2.41	0.25	0.45	1.67	205.00	34.80	108.00	5.03	1423
Magnetic-BW_2 (M-BW_2)	Sakha-94	1.45	2.50	0.23	0.27	1.44	151.00	33.39	113.33	5.03	650
	Masr-2	1.50	2.51	0.28	0.49	1.65	180.67	35.50	104.00	5.00	490
	Gemiza-11	1.45	2.46	0.27	0.47	1.51	224.00	29.80	103.00	5.01	1080
F test		ns	***	ns	***	*	***	ns	***	ns	***
$LSD_{5\%}$		0.24	0.24	0.17	0.22	0.25	1.07	2.51	2.33	0.86	20.74
Water treatment	BW	1.25	2.11	0.22	0.90	1.35	138.00	42.90	146.44	4.51	1446
	MBW_1	1.40	2.38	0.24	0.47	1.64	172.33	37.01	111.33	4.92	1034
	MBW_2	1.47	2.49	0.26	0.41	1.53	185.22	32.90	106.78	5.02	740
F test		***	***	ns	***	***	***	**	***	ns	**
$LSD_{5\%}$		0.03	0.03	0.02	0.03	0.04	0.67	3.69	3.17	0.43	251.33
Variety	Sakha-94	1.34	2.28	0.21	0.51	1.42	139.33	38.34	126.44	4.93	1423
	Masr-2	1.39	2.37	0.26	0.66	1.60	164.56	39.66	117.11	4.66	470
	Gemiza-11	1.38	2.33	0.25	0.60	1.51	191.67	34.80	121.00	4.86	1327
F test		*	***	***	***	***	***	*	***	ns	***
$LSD_{5\%}$		0.04	0.03	0.02	0.01	0.04	1.56	3.76	2.68	0.74	252.17
$CV_{\%}$		2.65	1.07	5.56	0.56	2.38	0.72	7.64	1.68	11.77	17.94

Table 6. Plant height, spike per meter square, 100-grains weight and spike characters at harvest of the three wheat varieties under different magnetic brackish water treatments

Treatment		Plant height (cm)	Spikes (no. m^2)	Spike character (s)				100-grains wt. (g)
Water	Variety			Length (cm)	Weight (g)	Grains wt. (g)	Spikelet's (no. $spike^{-1}$)	
Brackish water (BW)	Sakha-94	66.47	408	6.43	2.91	1.90	13.05	5.06
	Masr-2	70.33	480	6.62	3.14	2.10	15.57	4.74
	Gemiza-11	75.80	488	7.67	3.86	2.60	16.33	6.23
Magnetic-BW_1 (MBW_1)	Sakha-94	74.40	488	6.81	3.29	2.35	15.19	5.63
	Masr-2	78.67	604	7.86	3.47	2.45	16.81	5.22
	Gemiza-11	80.00	612	8.33	5.05	3.25	17.62	6.31
Magnetic-BW_2 (M-BW_2)	Sakha-94	76.67	552	7.10	3.60	2.35	16.62	6.21
	Masr-2	77.53	692	7.91	3.68	2.52	17.52	5.36
	Gemiza-11	84.60	624	8.51	5.42	3.35	17.71	6.82
F test		*	**	*	**	**	*	**
$LSD_{5\%}$		3.21	77	0.64	0.19	0.11	0.82	0.07
Water treatment	BW	70.87	458	6.90	3.30	2.20	14.98	5.34
	M-BW_1	77.69	568	7.67	3.94	2.68	16.54	5.72
	M-BW_2	79.60	622	7.84	4.23	2.74	17.29	6.13
F test		**	**	**	**	**	***	**
$LSD_{5\%}$		2.38	73.53	0.37	0.06	0.08	0.39	0.05
Variety	Sakha-94	72.51	482	6.78	3.27	2.20	14.95	5.64
	Masr-2	75.51	592	7.46	3.43	2.36	16.63	5.11
	Gemiza-11	80.13	574	8.17	4.78	3.07	17.22	6.45
F test		**	**	***	***	***	***	**
$LSD_{5\%}$		1.85	44.67	0.37	0.11	0.06	0.47	0.04
$CV_{\%}$		2.37	7.91	4.76	2.88	2.48	2.79	0.64

Table7. Grain, Straw and biological yield (ton fed^{-1}), harvest and crop indexes (%) at harvest of the three wheat varieties under different magnetic brackish water treatments

Treatment		Yield (ton fed^{-1})			Indexes (%)	
Water	Variety	Grains	Straw	Biol.	Harvest	Crop
Brackish water (BW)	Sakha-94	1.38	2.32	3.70	37.30	59.51
	Masr-2	1.44	2.58	4.02	35.75	55.75
	Gemiza-11	1.73	2.55	4.29	40.45	67.94
Magnetic-BW_1 (M-BW_1)	Sakha-94	1.60	2.52	4.12	38.74	63.28
	Masr-2	1.86	2.70	4.57	40.80	68.94
	Gemiza-11	1.89	3.45	5.34	35.40	54.79
Magnetic-BW_2 (M-BW_2)	Sakha-94	1.62	2.77	4.39	36.82	58.36
	Masr-2	1.89	3.32	5.21	36.23	56.85
	Gemiza-11	2.00	3.56	5.56	35.92	56.07
F test		*	**	*	**	**
$LSD_{5\%}$		0.11	0.15	0.18	2.07	5.22
Water treatment	BW	1.52	2.48	4.00	37.84	61.07
	MBW_1	1.78	2.89	4.67	38.31	62.34
	MBW_2	1.83	3.22	5.05	36.32	57.09
F test		***	**	***	**	**
$LSD_{5\%}$		0.06	0.06	0.12	0.64	1.62
Variety	Sakha-94	1.53	2.54	4.07	37.62	60.38
	Masr-2	1.73	2.87	4.60	37.59	60.51
	Gemiza-11	1.87	3.19	5.06	37.26	59.60
F test		**	**	**	ns	ns
$LSD_{5\%}$		0.06	0.09	0.10	1.19	3.01
$CV_{\%}$		3.63	2.84	2.18	3.11	4.88

Fig. 2. The three wheat varieties were irrigated with brackish water (BW) and magnetic-brackish water (M-BW) at initial vegetative stage

Fig. 3. The three wheat varieties were irrigated with magnetic-brackish water (M-BW) at maturity and harvest stage

respectively. Significant differences were recorded in wheat yield and its components at harvest due to the interaction between varieties and irrigation water treatments (Tables 6 and 7). Sowing Gemiza-11and irrigation with M-BW_1 or M-BW_2 gave the highest value of all recorded yield parameters, followed by Maser-2 and Sakha-94, respectively, while sowing the three wheat varieties and irrigation with brackish water (BW) gave the lowest values in yield and yield components parameters.

DISCUSSION

Application of magnetic technology treatments either on seeds and/or brackish- irrigation water can be used as an effective method for alleviation salinity stress and improving wheat crop productivity. The study indicated that there is a partial desalinization of soil and well water used for irrigation due to the magnetic technology application, but the effect was more pronounced for soil than the irrigated water (Hozayn *et al*., 2017; Hozayn and Ahmed, 2019 and Hozayn *et al.*, 2019a&b), where they found that magnetically treated brackish-water under gated or drip irrigation systems decreasing salinity stress due to leaching the most dominant soluble salts (Cl^- and Na^+) away from the spread of hairy roots and increasing the most of available nutrients (N, P, K and Mg) which reflected on improving the accumulated dry matter in plant organs and macro-nutrients in leaves of plants (i.e., sunflower, barley, alfalfa) at 60 DAS. The present study confirmed the above results where, irrigation wheat varieties (Sakha-94, Masr-2 and Gimeza-11) produced more values in the most of tested parameters (growth parameters i.e., plant height (cm), fresh and dry matter of tillers shoot (kg m^{-1}), flag leaf area ($cm^2 plant^{-1}$) as well as shoot contents of NPK and Mg at 75 DAS) under irrigation with M-BW_1 or M-BW_2 than irrigation with BW. Improving growth parameters regarding irrigation with magnetic brackish or normal-water also were reported in several studies on many crops (i.e., Hozayn *et al*., 2016; Surendran *et al*., 2016; Vladimir 2017; Razmkhaha *et al*., 2018)

Regarding micro-morphological characters, several studies reported that, salinity has almost effects on structural and functional aspects on plants (Bahaji *et al*., 2002), disrupt several cellular functions and physiological processes (Duarte *et al*., 2013). Structural changes include deep root system (Hameed *et al*., 2010), succulence for water storage (Grigore and Toma, 2008), thick epidermis along with dense deposition of cuticle (Ristic and Jenks, 2002) for minimizing water loss through plant surface and sclarification and hardening of plant organs for mechanical strength as well as water conservation (Evans *et al*., 2007). In our study, irrigation with magnetized brackish-water has positive impact on the most stem and lamina anatomical features of the three wheat varieties compared with brackish water treatment.

The stem diameter was increased in the three wheat varieties due to using M-BW_1 or M-BW_2. The increase in diameter reflects the increase in growth productivity and yield, respectively. The most characters in stem sections are the increase vascular bundles number, also the diameter of vessels increase and this led to increase the translocations of nutrients elements in plant and reflected in growth improvement. The epidermis thickness, cortex thickness, sclerenchyma thickness, parenchyma thickness and number of vascular bundles were increased obviously in the tested wheat varieties; sakha-94 and Masr-2 with using irrigation by MBW_1 or MBW_2 than irrigation with BW. The intensive sclerification and increase in thickness of layers not only provides mechanical strength to the plant but also prevents water loss through the stem surface (Evans *et al*., 2007; Hameed *et al*., 2010).

The lamina anatomical features *viz*; midrib thickness, wing thickness, bulliform cells development, mesophyll thickness, and midvein vascular supply varied significantly in the three varieties of wheat. The lamina anatomical features increased with using MBW^1 and MBW2. The most obvious anatomical characters of lamina is the well-developed bulliform cells which may provide functional advantage to the plant by minimizing water loss via leaf rolling (Grigore and Toma, 2008). The bulliform cells had increased with irrigation by magnetic water (MBW_1 or MBW_2), also the leaf rolling increase in contrast with irrigation by brackish water (BW), the leaf appeared flattened and this may enhance the water loss. Extensive sclerificationin the leaf sheath in addition to the thick cuticle and epidermis play a key role in preventing water loss (Hameed *et al*., 2010).

The positive results for morphological and micro-morphological characters under irrigation with magnetically brackish water, led to clear improving yield and yield components of the three wheat varieties. These results confirmed the previous studies under non-saline or saline condition in Ismailia, South Sinai and Nubaria regions (Hozayn e*t al*., 2013, 2016, 2017 and 2019a&b), where they revealed that, wheat, barley, faba bean, lentil, chickpea, sunflower, canola and ground nut, flax, sugar beet and potato irrigated with magnetized-water produced more values of growth, yield and quality compared untreated treatment. In abroad also, clear increasing (10.6-144.8%) in economic yield of many crops (i.e., cereal, wheat, rice, soybean, broad bean, sugar beet, sunflower, pepper and pea) were recorded under magnetic field treatments in macro experiments (i.e., Vasilevski 2003; Aladjadjiyan, 2007; Vashisth and Nagalajan, 2010; Surendran *et al*., 2016; Vladimir 2017; Razmkhaha *et al*., *et al*., 2018). They also recorded that, the increasing in yield were accompanied by improvement in quality parameters i.e., protein, oil, sugar, and carbohydrates percentage. Generally, change in some physical and chemical properties of water and soil may be reflected in the positive effects on growth, yield and water productivity under magnetic water treatments (Maheshwari and Grewal 2010; Surendran *et al*., 2016; Vladimir 2017; Razmkhaha *et al*., 2018 and Ben omer *et al*., 2018).

CONCLUSIONS

Under these conditions, could be concluded that irrigation wheat with magnetic-brackish irrigation water can be an effective method for alleviation salinity stress and improving wheat productivity.

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الملخص العربي

تاثير المعاملات المغناطيسية للمياه منخفضة الجودة على النمو، التركيب التشريحى وانتاجية القمح تحت ظروف الاجهاد الملحى

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تم اجراء تجربة حقلية في المحطة البحثية لمركز بحوث الصحراء برأس سدر بمحافظة جنوب سيناء خلال الموسم الشتوى٢٠١٧/١٨ وذلك بهدف دراسه تأثير استخدام المعالجة المغناطيسية لمياه الرى المالحة [i) M-BW[1]: المعالجة المغناطيسية لمياه الرى بعد تمريرها على وحدة مغناطيسية، روسية الصنع، قطرها ٣ بوصة، انتاج شركة التقنيات المغناطيسية ii) M-BW2: المعالجة المغناطيسية لمياه الرى بعد تمريرها على وحدة مغناطيسية، قطرها ٣ بوصة، انتاج شركة دلتا ووتر iii) الرى بدون معالجة مغناطيسية] على النمو والتركيب التشريحى و انتاجية ثلاثة اصناف من القمح (سخا-٩٤، مصر-٢ و جميزة-١١). تم ترتيب عاملى الدراسة فى تصميم القطع المنشقة مرة واحدة، حيث تم وضع معاملات الرى فى القطع الرئيسية والاصناف فى القطع المنشقة. اظهرت النتائج أن تطبيق معاملتى مغنطة مياه الرى M-BW1 او M-BW2 ادى الى تحسين واضح فى معظم صفات النمو للاصناف الثلاثة المختبرة (مثل ارتفاع النبات، تراكم المادة الغضة والجافة للنبات، مساحة ورقة العلم ومحتوى المجموع الخضرى من معظم العناصر الغذائية مثل النحاس، الحديد، الكالسيوم و النيتروجين بالمقارنة بالكونترول (BW) عند ٧٥ يوم من الزراعة. بينما تم تسجيل عكس الاتجاه بالنسبة لمحتوى المجموع الخضرى من الصوديوم، الماغنسيوم، الزنك والبرولين. كذلك تم تسجيل تحسن واضح فى التركيب التشريحى للسيقان والاوراق مثل عدد وسمك الخلايا، عدد وقطر الفجوات العصارية والاوعية وخاصة وعاء الخشب فى السيقان والذى عضد زيادة النموالخضرى نتيجة تطبيق معاملتى مغنطة المياه بالمقارنة بالكونترول. كما اوضحت النتائج زيادة واضحة فى محصول الفدان من الحبوب، القش والبيولوجى تحت معاملتى مغنطة المياه بالمقارنة بالكنترول. حيث ترواحت نسبة الزيادة الى ١٩,٢٤، ٣٣,٩٧ و ٢٦,٩٩%على الترتيب (متوسط تطبيق معاملتى الرى الممغنط بالمقارنة بالكونترول). يستنتج من هذه الدراسة دور التقنية المغناطيسية فى تخفيف الاجهاد الملحى والذى ينعكس على تحسين انتاجية محصول القمح عند زراعتة تحت مثل هذة الظروف.