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

Hozayn M. Mahmoud¹, Mohamed A. Salim², Amany A. Abd Monem³, and Aml A. El-Mahdy⁴

**ABSTRACT**

This study included two factors: 1) three irrigation water treatments i) Brackish-water (BW), ii) Magnetic-BW; brackish water after magnetization through passing a three inch static-magnetic unit produced by Delta Water Company and iii) Magnetic-BW; 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 irrigation systems. 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 BW1 or magnetically treated BW2 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 (cm² 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 varieties 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.

**Keywords** 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 al. 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, Ozgeet 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 salinewaterlogged conditions, formation of aerenchymatous
nodal roots has been reported to improve Na+ exclusion and hence salt tolerance in wheat (Triticum spp.; Saqibet 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 et 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; Aladjadyian, 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; brackish water after magnetization through passing a three inch static-magnetic unit produced by Delta Water Company iii) Magnetic-BW; 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 (29°60’28” N latitude and 32°68’96” 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 m² (15 m width x 4 m length) and sub plots with area 20 m² (5m width x 4m length). During seed bed preparation, 150 Kg fed⁻¹ calcium superphosphate (15.5% P₂O₅) 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% K₂O) 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 m² plants from each treatment were determined. Water content was determined according to Henson et al., (1981) using the following formula: WC = 100x(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) | Irrigation water |
|----------------------------------------|-----------------|------------------|
| pH                                     | 0-30            | 30-60            |
|                                        | 7.66            | 7.00             | 8.60 |
| EC (dSm²)                              | 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)

| Cation     | 0-30 | 30-60 | Irrigation water |
|------------|------|-------|------------------|
| Ca²⁺       | 38.22| 30.82 | 23.54            |
| Mg²⁺       | 27.44| 22.00 | 24.48            |
| Na⁺        | 58.33| 65.80 | 40.05            |
| K⁺         | 2.01 | 0.08  | 0.14             |

*SAR = Na/SQRT(Ca²⁺ + Mg²⁺)/2

Soluble anions (meq/L)

| Anion      | 0-30 | 30-60 | Irrigation water |
|------------|------|-------|------------------|
| CO₃⁻       | 0.00 | 0.00  | 0.00             |
| HCO₃⁻      | 3.44 | 2.00  | 4.50             |
| SO₄²⁻      | 58.93| 65.20 | 29.23            |
| Cl⁻        | 64.14| 51.50 | 48.94            |

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 deparaffinized 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: Macronutrients, N, P, K, Mg, Ca, Na, and micro-nutrients Fe, Mn, Zn and Cu 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/m² as 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 m² 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 (LSD5%) test was used to compare among the means.

RESULTS AND DISCUSSION

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 (cm² plant⁻¹) are recorded in Table 2. Regarding irrigation water treatments, the data reveals that, irrigation with magnetically treated brackish-water₁ (M-BW₁) or magnetically treated brackish-water₂ (M-BW₂) 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-BW₁ or M-BW₂ 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 (cm² 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-BW₁ and M-BW₂) 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-BW₁ or M-BW₂ 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 MBW₁ and MBW₂ than irrigation by BW. In Gemiza-11, the cortex thickness, sclerenchyma thickness,
Table 2. Plant height, fresh and dry mater of shoot (kg m² plant⁻¹), and flag leaf area (cm² plant⁻¹) at 75 DAS of the three wheat varieties under different magnetic brackish water treatments

| Treatment                  | Variety   | Plant height (cm) | Tiller weight (kg/m²) | Water content (%) | Flag leaf area (cm² plant⁻¹) |
|----------------------------|-----------|-------------------|-----------------------|------------------|-------------------------------|
|                            |           |                   | 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-BW₁ (M-BW₁)       | 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-BW₂ (M-BW₂)       | 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                            | ***                           |
| LSD₉⁵                   |           | 5.48              | 0.10                 | 0.08             | ns                            | 2.44                          |
| Water treatment BW        |           |                   |                      |                  |                               |
|                            | Masr-2    | 63.77             | 4.12                 | 0.79             | 80.76                         | 34.60                         |
|                            | Gemiza-11 | 64.17             | 4.15                 | 0.82             | 80.20                         | 34.08                         |
| F test                     |           | **                | **                   | **               | ns                            | *                             |
| LSD₉⁵                   |           | 1.98              | 0.09                 | 0.12             | ns                            | 3.47                          |
| Variety Masr-2            | Sakha-94  | 55.20             | 3.26                 | 0.64             | 80.29                         | 24.94                         |
|                            | Gemiza-11 | 58.20             | 3.77                 | 0.73             | 80.88                         | 35.04                         |
| F test                     |           | ***               | ***                  | ***              | ns                            | ***                           |
| LSD₉⁵                   |           | 1.36              | 0.06                 | 0.05             | ns                            | 1.31                          |
| CV⁰                     |           | 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       | MBW₁   | MBW₂      | BW       | MBW₁   | MBW₂      | BW       | MBW₁   | MBW₂      |
| 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   | 1.50      | 2.00     | 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        |          |        |           |          |        |           |          |        |           |
| 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

| Lamina anatomy character | Sakha-94 | Masr-2 | Gemiza-11 |
|--------------------------|---------|-------|-----------|
|                          | BW      | MBW₁  | MBW₂      | BW      | MBW₁  | MBW₂      |
| 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    | 5.00  | 3.00      | 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 | + +   |

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-BW₁ and M-BW₂. The lamina anatomical features were increased with using M-BW₁ and M-BW₂ (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 Gemiza-11) contained more values of macro and micro-nutrients in shoot at 75 DAS, except Na, Mn and Zn, under irrigation with M-BW₁ or M-BW₂ than irrigation with Brackish-water (BW). Gemiza-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-water₁ (M-BW₁) or magnetically treated brackish-water₂ (M-BW₂) 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/m², 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  | Sakha-94                     | 1.20 | 2.07 | 0.19 | 0.85| 1.30| 125.00 | 43.39| 148.00| 4.50| 2360  |
| (BW)            | 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-BW₁    | Sakha-94                     | 1.38 | 2.27 | 0.22 | 0.40| 1.51| 142.00 | 38.25| 118.00| 5.27| 1260  |
| (M-BW₁)         | 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-BW₂    | Sakha-94                     | 1.45 | 2.50 | 0.23 | 0.27| 1.44| 151.00 | 33.39| 113.33| 5.03| 650   |
| (M-BW₂)         | 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   | ***  |       |
| LSD₅₀           | 0.24 | 0.24 | 0.17 | 0.22 | 0.25| 1.07 | 2.51  | 2.33  | 0.86 | 20.74 |
| Water           | 1.25 | 2.11 | 0.22 | 0.90 | 1.35| 138.00 | 42.90| 146.44| 4.51| 1446  |
| treatment       | 1.40 | 2.38 | 0.24 | 0.47| 1.64| 172.33 | 37.01| 111.33| 4.92| 1034  |
| MBW₁            | 1.47 | 2.49 | 0.26 | 0.41| 1.53| 185.22 | 32.90| 106.78| 5.02| 740   |
| F test          | ***  | ***  | ns   | ***  | *** | *** | ns   | ***  | **   |       |
| LSD₅₀           | 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   | ***  |       |
| LSD₅₀           | 0.04 | 0.03 | 0.02 | 0.01| 0.04| 1.56  | 3.76  | 2.68  | 0.74| 252.17|
| CV₅₀           | 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            | Variety | Plant height (cm) | Spikes (no. m²) | Spike length (cm) | Weight (g) | Grains wt. (g) | Spikelet’s length (cm) | 100-grains wt. (g) |
|----------------------|---------|-------------------|-----------------|-------------------|------------|---------------|------------------------|-------------------|
| 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-BW₁ (MBW₁) | 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              |
|                      | Sakha-94| 76.67             | 552             | 7.10              | 3.60       | 2.35          | 16.62                  | 6.21              |
| Magnetic-BW₂ (MBW₂) | 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              |

| Treatment            | F test | LSD5% | * | ** | *** | ** | *** | ** | *** | ** |
|----------------------|--------|-------|---|----|-----|----|-----|----|-----|----|
| Water                |        |       |   |    |     |    |     |    |     |    |
| Brackish water (BW)  |        | 3.21  | 77 | 0.64 | 0.19 | 0.11 | 0.02 | 0.07 |      |    |
| Water treatment      |        | 70.87 | 458 | 6.90 | 3.30 | 2.20 | 14.98 | 5.34 |      |    |
| Variety              |        | 77.69 | 568 | 7.67 | 3.94 | 2.68 | 16.54 | 5.72 |      |    |
| Variety              |        | 79.60 | 622 | 7.84 | 4.23 | 2.74 | 17.29 | 6.13 |      |    |
| Variety              |        | 3.28  | 73.53 | 0.37 | 0.06 | 0.08 | 0.39 | 0.05 |      |    |
| Variety              |        | 72.51 | 482 | 6.78 | 3.27 | 2.20 | 14.95 | 5.64 |      |    |
| Variety              |        | 75.51 | 592 | 7.46 | 3.43 | 2.36 | 16.63 | 5.11 |      |    |
| Variety              |        | 80.13 | 574 | 8.17 | 4.78 | 3.07 | 17.22 | 6.45 |      |    |
| CV%                  |        | 2.37  | 7.91  | 4.76 | 2.88 | 2.48 | 2.79 | 0.64 |      |    |

Table 7. 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            | Variety | Yield (ton fed⁻¹) | Indexes (%) |       |
|----------------------|---------|------------------|-------------|-------|
| Water                |         |                  | 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-BW₁ (MBW₁) | 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   |      |
|                      | Sakha-94| 1.62             | 2.77        | 4.39 | 36.82 | 58.36   |      |
| Magnetic-BW₂ (MBW₂) | 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               |         |                 | *           | **   | ***   | **      | **    |
| LSD5%                |         | 0.11             | 0.15        | 0.18 | 2.07  | 5.22    |      |
| Water treatment      |         | 1.52             | 2.48        | 4.00 | 37.84 | 61.07   |      |
| MBW₁                 |         | 1.78             | 2.89        | 4.67 | 38.31 | 62.34   |      |
| MBW₂                 |         | 1.83             | 3.22        | 5.05 | 36.32 | 57.09   |      |
| F test               |         |                 | ***          | **   | ***   | **      | **    |
| LSD5%                |         | 0.06             | 0.06        | 0.12 | 0.64  | 1.62    |      |
| Variety              |         | 1.53             | 2.54        | 4.07 | 37.62 | 60.38   |      |
| Variety              |         | 1.73             | 2.87        | 4.60 | 37.59 | 60.51   |      |
| Variety              |         | 1.87             | 3.19        | 5.06 | 37.26 | 59.60   |      |
| 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.
The three wheat varieties were irrigated with magnetic-brackish water (M-BW) at maturity and harvest stage. 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-11 and 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 sclarifraction 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 MBW\(_2\). 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 irradiation 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 et 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 Nagalalaj, 2010; Surendran et al., 2016; Vladimir 2017; Razmkhaha 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.
REFERENCE

Aladjadiyan, A. 2007. The use of physical methods for plant growing stimulation in Bulgaria. Central Eur. Agric. 8(30): 369-380.

Aldesuquy, H., S. Baka and B. Mickly. 2014. Kinetin and spermine mediated induction of salt tolerance in wheat plants: Leaf area, photosynthesis and chloroplast ultrastructure of flag leaf at ear emergence. Egyp. J. Basic and Appl. Sci. (1): 77-87.

Bahaji, A., I. Mateu, A. Sanz and M. J. Cornejo. 2002. Common and distinctive responses of rice seedlings to saline and osmotically generated stress. Plant Growth Regulation (38): 83-94.

Bates, L.S., R.P. Waldan, L.D. Teare. 1973. Rapid determination of free proline under water stress studies. Plant and Soil. (39): 205-207.

Ben Omer, H., A. Elaoud and M. Hozayn. 2018. Does magnetic field change water ph? Asian Res. J. of Agri. 8(1): 1-7.

Chanda, S.V. and Y.D. Singh. 2002. Estimation of leaf area in wheat using linear measurements. Plant Breeding and Seed Science, (46): 75-79.

Chapman., H.O and P.E. Pratt. 1978. Methods of Analysis for Soils, Plants and Water. Univ. of California Agric. Sci. Priced Publication. 4034. pp: 50.

Duarte, B., D. Santos, J. C. Marques and I. Cac, ador. 2013. Ecophysiological adaptations of two halophytes to salt stress: Photosynthesis, PS II photochemistry and antioxidant feedback – Implications for resilience in climate change. Plant Physiology and Biochemistry. (67): 178–188.

Eames, A.J. and L.H. MacDaniels. 1947. Introduction to Plant anatomy.2nd edn, McGraw-Hill, New York.427 p.

Evans, S. L., Z. Kahn-Jetter, C. Marks and K. R. Harmaney. 2007. Mechanical properties and anatomical components of stems of 42 grass species. J. of the Torrey Bot. Soc. (134): 458-467.

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

Grigore, M. N and C. Toma. 2008. Ecological anatomy investigations related to some halophyte species from Moldavia. Romanian J of Biol.-Plant Biol. (53): 23–30.

Hameed, M., M. Ashraf., M.S.A. Ahmad and N. Naz. 2010. Structural and Functional Adaptations in Plants for Salinity Tolerance, in M. Ashraf et al. (eds.), Plant Adaptation and Phytoremediation (Chapter 8). Springer, Science & Business Media. B.V.

Hameed, M., S.M.A. Basra and N. Naz. 2009. Anatomical adaptations to salinity in cogon grass (Imperata cylindrica L.) Raueschel from the Salt Range, Pakistan. Plant and Soil 322(1): 229-238.

Henson, I.E., Y. Mahalakshmi., E.R. Bidinger and G. Alagarswamy. 1981. Genotypic variation in pearl millet (Pennisetum americanum (L.) (L.) Leeke) in the ability to accumulate abscisic acid in response to water stress. J. Exp. Bot. 32: 899-910.

Hozayn M., A.A. Abd El Monem, R.E. Abdelraouf, and M.M. Abdalla, (2013). Do Magnetic Water affect Water Use Efficiency, Quality and yield of Sugar Beet (Beta vulgaris L.) plant under Arid Regions Conditions?. Journal of Agronomy. 12 (1): 1-10.

Hozayn, M and A.A. Ahmed. 2019. Effect of Magnetopriming by tryptophan and ascorbic acid on germination attributes of barley (Hordeum vulgare, L.) under salinity stress. EurAsian J. BioSci. 13(1): 245-251.

Hozayn, M., A.A. Abd El-Monem and A.A. Elmahdy 2017. Application of magnetic technology for salinity stress mitigation and improving sunflower productivity under South Sinai conditions. Middle East Journal of Agriculture Research. 6(4): 1490-1500.

Hozayn, M., A.A. El-Mahdy and M.H.M. Abdel-Rahman. 2015a. Effect of magnetic field on germination, seedling growth and cytogenetic of onion (Allium cepa L.). Afric. J. of Agric. Res. 10(8): 849-857.

Hozayn, M., H.M.S. El-Bassiouny, A.A. Abd El-Monem and M.M. Abdallah. 2015b. Applications of magnetic technology in agriculture, a novel tool for improving crop productivity (2): Wheat. Inter. of J. Chem. Tech. Res., Vol. 8(12): 759-771

Hozayn, M., M.A. Salama, A.A. El-Monem and H.F. Alharby. 2016. The impact of magnetized water on the anatomical structure, yield and quality of potato (Solanum tuberosum L.) grown under newly reclaimed sandy soil. Res. J. of Pharma., Biol. and Chem. Sci. 7(3):1059-1072.

Hozayn, M., M.M. Abdallha, A.A. Abd El-Monem, A.A. El-Saady and M.A. Darwish. 2016. a. Applications of magnetic technology in Agriculture, a novel tool for improving crop productivity, (1): Canola. Afric. J. of Agric. Res., Vol. 11(5): 441-449.

Hozayn, M., S.M. Ismail, A.A. Abd El-Monem and M.M. Darwish. 2019b. 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):441-461.

Hozayn., M., A.A. Ahmed, A.A. El-Saady and A.A. Abd-Elmonem. 2019a. Enhancement in germination, seedling attributes and yields of alfalfa (Medicago sativa, L.) under salinity stress using static magnetic field treatments. EurAsian J. BioSci. 13(1): 369-378.

Johanson, D. A. 1940. Plant Microtechnique. New York Book Company. p. 523.

Maheshwari, B.L. and H.S. Grewal. 2010. Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity. Agricultural Water Management. 96(8): 1229-1236.
Hozayn M. Mahmoud et al.: Effect of Magnetic Brackish-Water Treatments on Morphology, Anatomy and Yield Productivity.

Metcalfe, C. R. and L. Chalk. 1950. Anatomy of dicotyledons, vol 2. Clarendon Press, Oxford, England.

Moussa, H.R. 2011. The impact of magnetic water application for improving common bean (Phaseolus vulgaris L.) production. New York Sci. J. 4(6):15-20.

Nawazish, S., M. Hameed and S. Naurin. 2006. Leaf anatomical adaptations of Cenchrus ciliaris L. from the Salt Range, Pakistan against drought stress. Pakistan J. Bot. (38): 1723-1730.

Özge, Ç., A. Çimen, R. Aitekin. 2008. Stimulation of rapid regeneration by a magnetic field in paulownia node cultures. J. Cent. Eur. Agric. 9(2): 297-304.

Razmkhaha, M., F. Moosavib, M.T.H. Mosaviana and A. Ahmadpour. 2018. Does electric or magnetic field affect reverse osmosis desalination? Desalination. (432):55-62.

Ristic, Z. and M.A. Jenks. 2002. Leaf cuticle and water loss in maize lines differing in dehydration avoidance. J. Plant Phys. (159):645-651.

Saqib, M., C. Zorb, Z. Rengel, and S. Schubert. 2005. The expression of the endogenous vacuolar Na+/H+ antiporters in roots and shoots correlates positively with the salt resistance of wheat (Triticum aestivum L.). Plant Sci. (169): 959-965.

Surendran., U., O. Sandeep, E.J. Joseph. 2016. The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics. Agric. Water Manag. (178):21-29.

Turker, M., C. Temirci, P. Battal, M.E. Erez. 2007. The effects of an artificial and static magnetic field on plant growth, chlorophyll and phytohormone levels in maize and sunflower plants. Phyton Ann. Rei. Botanicae. 46(2): 271-284.

Vashisth, A. and S. Nagarajan. 2010. Effect on germination and early growth characteristics in sunflower (Helianthus annuus L.) seeds exposed to static magnetic field. J. Plant Physiol. 167 (2): 149-156.

Vasilevski., G. 2003. Perspectives of the application of biophysical methods in sustainable agriculture. Bulg. J. Plant Physiol., Special Issue: 179-186.

Vladimir, Z. 2017. The impact of magnetic water treatment on salt distribution in a large unsaturated soil column. Int. Soil. and Water Cons. Res. (5) :253-257.

Wahid, A. 2003. Physiological significance of morpho-anatomical features of halophytes with particular reference to Cholistan flora. Int. J. Agric. and Biol. (5): 207-212.

Zhu, J.K. 2002. Salt and drought stress signal transduction in plants. Ann. Rev. Plant Bol. (53): 247-273.
تأثير المعاملات المغناطيسية للمياه منخفضة الجودة على النمو، التركيب التشريحي ونتاجية القمح تحت ظروف الاجهاد الملحى

محمود حزين محمود، محمد عبد الفتاح سالم، إمانة علي عبد المنعم وامام علي المهدي

تم إجراء تجربة حقلية في المحطة البحثية لمركز بحوث الصحراء بدراس سدر بمحافظة جنوب سيناء خلال الموسم الشتوي 2017/18 وذلك بهدف دراسة تأثير استخدام المعالجة المغناطيسية لمياه الرى المالحة (M-BW1) والمغناطيسة لمياه الرى بعد تمريرها على وحدة مغناطيسية، روسية الصنع، قطرها 3 بوصة، انتاج شركة القهوة (M-BW2) لمياه الرى بعد تمريرها على وحدة مغناطيسية، قطرها 3 بوصة، انتاج شركة دتلا ووتر (M-BW3) الرى بدون معالجة مغناطيسية على النمو والتركيب التشريحي ونتاجية ثلاثة أصناف من القمح (سخا-44، مصر-2 وجميلة-11). تم ترتيب عامل الدراسة في تصميم القطع المشدقة مرة واحدة، حيث تم وضع معاملات الرى في القطع الرئيسية والاصناف في القطع المشدقة. أظهرت النتائج أن تطبيق معاملة مغناطيسية مياه الرى مساعدة على تحسين نتائج محقول القمح عند زراعة نباتات البقولية المتنوعة، مثل ارتفاع النباتات، توازن المادة الغذائية، والجافة للنباتات، وساحة ورقة العلم ومجموع الخضروات من