Using Magnetic Technologies in Management of Water Irrigation Programs under Arid and Semi-Arid Ecosystem

Abstract

Agriculture in arid and semi-arid regions is currently affected by lack of fresh water and a remarkable increase in salt saline soil and underground water. Recently the available information of simple and eco-friendly technology, in using magnetic field in correcting brackish water is possible. Field experiments were carried out at Agricultural Research Station, College of Food and Agriculture Sciences, King Saud University, Saudi Arabia, aimed at examine whether there are any beneficial effects of magnetic treatment on correcting underground brackish water for irrigation. The experiments included three cereal crops viz., wheat, barley and triticale and three types of water i.e., magnetized and non-magnetized underground brackish water and treated wastewater. A magnetic unit for water treatment (magnetron) with magnetic field amounting to 1000 mT was installed to flow out magnetized water through a magnetic field. Overall, the results indicate that the effects of magnetic treatment varied with plant type and the type of irrigation water used, and their interaction. In particular, the magnetic treatment of underground water respectively increased germination percentage, nearly the complete emergence was recorded after 12 days from sowing (93.33 %) as compared to non-magnetized and treated waste water (86.00 and 76.66 %). Furthermore, magnetic water induced positive significant effect on mobility and uptake of micronutrient concentration (ppm) Fe, Zn and Mn. Using magnetized water also increased significantly all growth criteria including main stem height cm; number of tillers/ m2; fresh and dry weight g/m2 as compared to underground water; mounting to 4.3 % 3.8 %, 4.7 % and 10.6 % at heading stages, respectively. And thus all these parameters reflected in increasing biomass and finally grain yield. While the findings of the present study are interesting, the potential of the magnetic treatment of irrigation water for crop production needs to be further tested under different conditions.

Keywords: Grain germination; Magnetized water; Nutrients uptake; Water salinity; Yield

Introduction

On a global scale, water is plentiful; 97 % is saline and 2.25 % is trapped in glaciers and ice, leaving only 0.75 % available as fresh water in aquifers, rivers and lakes. Most of this fresh water (69 %) is used for agricultural production, 23% for industrial purposes and 8% for domestic purposes, Prathapar [1] and Abu-Zaid [2]. Whenever good quality water is scarce, water of marginal quality considered for use in agriculture sector Liang et al. [3], Abd EL-Lateef et al. [4] and Selim [5]. In arid and semi-arid zones, sustainable agricultural development is influenced to a great extent by sources of water that might be used economically and effectively in developing agricultural programs. Soil desalination under such conditions is also a critical problem facing agriculture, Behrouz [6]. The early studies of Oleshko et al. [7] and Takatshinko [8] highlighted using cheap magnetic energy could improve the physical and or chemical properties of soil and water quality. They stated that dissolving capacity of the soil can improved by using magnetized water. In the same concern, Zhu et al. [9] also reported in laboratory research that desalination of a saline soil was 29% greater in the first leaching and 33% greater in the second leaching with magnetized water compared to non-magnetized water. Also, The effect of magnetic fields on biological systems have been reported by many researchers; Moon and Chung[10], Reina et al. [11]; De Souza et al. [12,13], Tenuzzo et al. [14], Chou [15], Florez et al. [16], Trebbi et al. [17], Maheshwari & Grewal [18] The beneficial effects of magnetically treated irrigation water have also been reported on germination percentages by Reina et al. [1]. Reina & Pascual [19] studied the impact of magnetic treatment by exposing broad bean seeds to variable magnetic strengths before sowing and observed beneficial effects on seed germination and emergence. The experiments of Nan Yan & Petra Marschner [20] supported the studies of Khoshravesh et al. [21] indicated that there are some beneficial effects of magnetic treatment in the activity of soil microbial. However, there is no dear understanding yet as to the mechanisms behind these effects and the changes that magnetic treatment brings about in nutritional aspects of seed germination, seedling growth, physiological prosess and yield. Therefore, the present research was carried out to study the applicability of using magnetic field for underground brackish water desalinization to increase growth, micronutrient concentration and yield of some crops.

Materials and Methods

Plant material, treatments and experimental conditions

The study was laid out as field experiments in two growing
winter seasons of (2009 /2010 and 2010/2011) at the Agricultural Research Station, College of Food and Agriculture Sciences, Derab, Riyadh, King Saud University, Saudi Arabia (24o:42N latitude and 46o:44E Longitudes, Altitude 600 m) in a split plot design with 4 replications, to evaluate effectiveness of magnetic technology in correcting underground brackish water for irrigation. The experiment included irrigation with non-magnetizing underground water; treated wastewater compared to magnetizing underground water (for magnetizing water, magnetron type U.T 6 (1000 mT), with 6 inch diameter was used) and treated waste water arranged in main plots, where selected crops (wheat, barley and triticale) occupied the subplots (Figure 1). Prior to the field experiments, soil samples within 0-30 cm depth from eight sites were collected for soil physical and chemical analyses (Table 1 & 2) by the method described by Cottenie et al. [22] and Burt [23]. Following physical and chemical parameters are analyzed: soil texture, clay content, organic matter content, pH, soil macronutrients; N, P and K and soil micronutrients; Fe, Zn, Mn and Cu. Water irrigation was also analyzed according to the methods described by APHA [24]. Experimental soil sites were divided into plots; each plot consisted of 8 lines 20 cm apart, 3m in length. Plot area was 4.80 m². To avoid the effect of lateral movement of irrigation water, the strips were isolated by borders of 3 meters in width among the subplots (Figure 1). Grains were sown on the proper sowing date by hand drilled in hills 5 cm apart (approximately five seeds per hill at 2 cm depth). All agricultural practices were followed according to the recommendation of extension service.

Figure 1: Layout of field experimental design and treatments.

Table 1: Physical and chemical analysis of soils from the study sites.

| Texture          | O.M % | CaCO₃ % | Physical Analysis | Salinity | pH | Depth |
|------------------|-------|---------|-------------------|----------|----|-------|
| sandy clay loam  | 0.45  | 29.9    | Clay % | Silt % | Fine Sand % | Coarse sand % | EC dS/m | 1.5  | 8.6 | 0 - 60 |

Table 2: Chemical composition of treated wastewater and underground brackish water used in irrigation Treatments.

| EC    | pH  | SAR | Ca⁺ | Mg⁺ | Na⁺ | K⁺ | CO₃⁻ | HCO₃⁻ | Cl⁻ | SO₄²⁻ |
|-------|-----|-----|-----|-----|-----|----|------|-------|-----|-------|
| dS/m  |     |     |     |     |     |    |      |       |     |       |
| 1.4   | 6.2 | 2.7 | 100 | 30  | 121 | 13.7| 1.48 | 83.9  | 146.3| 408.2 |
| 6.6   | 8   | 7.7 | 360 | 216 | 752 | 22.2| 18.8 | 198   | 896.4| 1744.6|
| 6.5   | 7.8 | 7.7 | 360 | 216 | 752 | 22.2| 18.8 | 198   | 896.4| 1744.6|

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Table 3: Germination percentage of cereal crops studied as affected by different water irrigation sources (means of two seasons).

| Water treatment                | Crop      | Emergence Hills Counts in 3 Lines One Meter Length After | Germination Percentage (%) |
|-------------------------------|-----------|----------------------------------------------------------|-----------------------------|
|                               |           | 6 days | 9 days | 12 days | 6 days | 9 days | 12 days |
| Underground brackish water    | wheat     | 21     | 30     | 42      | 35     | 50     | 70      |
|                               | Barley    | 24     | 36     | 48      | 40     | 60     | 80      |
|                               | Triticale | 34     | 44     | 48      | 57     | 74     | 80      |
| General Mean of underground water | wheat   | 26.3   | 36.7   | 46      | 44     | 61.3   | 76.6    |
|                               | Barley    | 24     | 36     | 48      | 40     | 60     | 80      |
|                               | Triticale | 34     | 44     | 48      | 57     | 74     | 80      |
| Magnetized water              | wheat     | 34     | 42     | 53      | 57     | 70     | 89      |
|                               | Barley    | 36     | 46     | 56      | 60     | 77     | 94      |
|                               | Triticale | 39     | 47     | 58      | 65     | 79     | 97      |
| General Mean of Magnetic Treatment | wheat | 36.3   | 45     | 55.7    | 61     | 75.33  | 93.3    |
|                               | Barley    | 34     | 42     | 53      | 57     | 70     | 89      |
|                               | Triticale | 39     | 47     | 58      | 65     | 79     | 97      |
| Treated waste water           | wheat     | 28     | 36     | 48      | 47     | 60     | 80      |
|                               | Barley    | 33     | 42     | 52      | 55     | 70     | 87      |
|                               | Triticale | 35     | 45     | 56      | 59     | 75     | 93      |
| General Mean of Treated waste water | wheat | 32     | 41     | 52      | 54     | 68.33  | 86      |
|                               | Barley    | 31     | 41.33  | 52      | 52     | 69     | 87      |
|                               | Triticale | 36     | 45.33  | 54      | 60     | 76     | 90      |

Data collecting

Grain germination percentage, micronutrients concentration and some growth criteria: Germinating seeds after 6, 9 and 12 days from sowing were counted in 3 lines one meter length, then germination percentage was calculated. Two representative samples were taken during growth (after 45 and 90 days from sowing). Three plants from each sub plots were hand pulled randomly for measuring Growth criteria viz., main stem height cm; number of tillers/m2; fresh and dry weight g/m2 and dried. Sub samples were also taken for measuring dry matter, and dried in an oven at 70°C for 24 hours and weighed till constant weight. Other samples were grinded in porcelain mortar by hand to avoid any source of contamination. Samples were wet-ached with a mixture of nitric, per chloric and sulfuric acid (8:1:1). Micronutrients (Fe, Zn, Mn) in the digest were measured in ppm by atomic absorption spectrophotometer (AAS-Model Number, Company Name, City, Country).

Yield and yield component characters: At the harvest time (nearly after 120 days from sowing), a sample of square meter (m2) was randomly pulled from two inner center lines of each sub plots to determine grain yield and yield component characters viz., number of spike m2, spike length cm, number of grains per spike, seed index (weight of 1000 grains) and grain weight per m2, straw yield ton /ha., and biological yield ton/ha.

Statistical analysis: Data for each season were statistically analyzed according to Gomez and Gomez [25]. The data in both seasons were took similar trends and variance was homogeneous according to Barlet test, therefore, combined analysis of the data of the two seasons were carried out. Whenever the results were p<0.05 significant, means were compared using L.S.D test which suggested by Waller and Duncan [26].

Results and Discussion

Effect of magnetic treatments on grain germination

Many of the germinating seeds might fail to emerge especially in stress conditions. Saline soil or saline water or both are the most important factors effecting seed germination. Therefore, number of seedling seeds may express some tolerance. As shown in Table 3, the percentage of germinated seeds and time required
for germination revealed that among the different treatments, magnetizing water caused significant effect on germinating seeds. Nearly, full germination rate of 93.33 % was obtained after 12 days from sowing crows all tested treatments compared to either underground or treated waste water with seed germination percentage 76.66% and 86.00%, respectively. These results are similar to those obtained by [8] where magnetic water caused a full germination rate of 100 % after 6 days from sowing compared to only 83% germination after 9 days from sowing untreated water (control) in his study. Based on previous research findings, seeds carry various load of energy therefore, not all of them will eventually sprout. Water previously treated in a stationary magnetic field has more ability to absorb by seeds. The mechanism plant and other living systems uses when they are exposed to a magnetic field are not well known yet. However, several theories have been proposed including biochemical changes or altered enzyme activities or the effect of magnetic field in rearrange ionic water of molecular which reflected in water properties [12,21], De Souza et al. [13], Chang & Weng [27] and Harsharn & Basant [28], Namba et al. [29], Atak et al. [30] and Reina et al. [11]. They stated that the manner magnetic field decreases the effect of germination inhibitors because of increase in pH of the cell juice can substitute for such expensive material. This finally reflected in seed germination percentage. The results given in Table 3. Also indicated that triticale succeeded to produce significantly highest values of germination percentage of 90.00% compared to 79.67 and 87.00 % for wheat and barley, respectively. The present results are in agreement with those obtained by [5].

Effect of magnetic treatments on micronutrients concentration

Among the different water treatments, magnetized water caused significant effect on micronutrients concentrations, Fe, Zn and Mn at heading stage for the three crops under investigation (Table 4). Such increment due to magnetized water may be attributed to the effect of MF in increasing ions mobility in root zone and ions uptake by the plants which are differed greatly from one element to another according to the element magnetic field. Similar results were also reported by previous investigators for different crops; Atak et al. [31] found that MF significantly increased micronutrients and chlorophyll contents in soybean (Glycine max L. Merrill) leaves. The study by Selim [5] under Egyptian condition also confirmed that magnetized water irrigation induced changes in solubility of some soil components such as CaCO3 and gypsum; this is turn favorably influenced soil enzyme activities or the effect of magnetic field in rearrange ions of water molecular which reflected in water properties [12,21], De Souza et al. [13], Chang & Weng [27] and Harsharn & Basant [28], Namba et al. [29], Atak et al. [30] and Reina et al. [11]. They stated that the manner magnetic field decreases the effect of germination inhibitors because of increase in pH of the cell juice can substitute for such expensive material. This finally reflected in seed germination percentage. The results given in Table 3. Also indicated that triticale succeeded to produce significantly highest values of germination percentage of 90.00% compared to 79.67 and 87.00 % for wheat and barley, respectively. The present results are in agreement with those obtained by [5].

Effect of magnetic treatments on Growth criteria

The changes in growth characters at different growth stages such as tillering and heading stages for some cereal crops are affected by magnetizing water irrigation as compared to irrigation with either underground water or treated waste water shown in Table 5. The results show that magnetic water significantly increased all growth criteria including main stem height cm; number of tillers/m2; fresh and dry weight g/m2 as compared to underground water, with the percentage of increments reach to 5.4 %, 4.4 %, 0.15 %, and 3.19 % and 4.3 % 3.8 %, 4.7 % and 10.6 % in the above mention parameters at tillering and heading stages, respectively. In this connection, Nasher [32] and Shabragni & Majd [33] concluded that magnetized water increased the plant growth and this is reflected in biomass increase, an important factor for inducing plant growth. Celik et al. [34] and Nasher [32] discovered that the stimulatory effect of magnetic water on the growth parameters may be due to its effect on biochemical changes or altered enzyme activities. Data in the same Table 5 also indicated that irrigation with treated waste water surpassed both water irrigation treatments in terms of plant growth criteria. Such effect may be due to the higher nutrient content in the wastewater. Hence the plants were supplied with adequate nutrients for proper growth and metabolic processes. This in turn reflected in better rates of all growth parameters and better plant growth. The results of our study show that, triticale plants surpassed wheat and barley and the highest values of above parameters at the two growth stages were recorded, followed by barley (Table 5).

| Water treatment     | Crop   | Micro Nutrient Concentration (ppm) |
|---------------------|--------|-----------------------------------|
|                     |        | Fe      | Zn      | Mn      |
| Magnetic water      | Wheat  | 178     | 88      | 65      |
|                     | Barely | 174     | 79      | 67      |
|                     | Triticale | 170   | 80      | 67      |
| General Mean of Magnetic Treatment | Wheat | 174 | 82.3 | 66.3 |
|                     | Barely | 140     | 72      | 60      |
|                     | Triticale | 144 | 73      | 58      |
| General Mean of under-ground water | Wheat | 148.6 | 71.7 | 58.3 |
|                     | Barely | 158     | 73      | 66      |
|                     | Triticale | 164 | 76      | 65      |
| Treated waste water | Wheat  | 163.7   | 75.3    | 64.3    |
|                     | Barely | 159.3   | 76.3    | 63.3    |

Table 4: Effects of different water irrigation sources on micronutrients concentration of the field crops at heading stage (means of two seasons).

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Table 5: Growth characters at different growth stages of cereal crops as affected by sources of water irrigation (means of two seasons).

| Water Treatment      | Crop      | Tillering Stage |          |          | Heading Stage |          |          |
|----------------------|-----------|-----------------|----------|----------|---------------|----------|----------|
|                      |           | Main stem height cm | No. of tillers/m² | Fresh weight g/m² | Dry weight g/m² | Main stem height cm | No. of tillers/m² | Fresh weight g/m² | Dry weight g/m² |
|                      | Wheat     | 49.9            | 475.6    | 849.4    | 186.9         | 61.5     | 484      | 1240.2   | 268.6         |
|                      | Barely    | 50.6            | 478.4    | 848.2    | 187.5         | 62.2     | 489      | 1246.9   | 279.6         |
|                      | Triticale | 52.9            | 495.5    | 899.8    | 198.5         | 64.3     | 490      | 1258.2   | 288.7         |
| General Mean of      | Wheat     | 51.1            | 483.2    | 865.8    | 191           | 62.7     | 488      | 1248.4   | 279           |
| Magnetic Treatment   | Barely    | 47.9            | 454.3    | 824.5    | 178.4         | 60.5     | 479      | 1230.6   | 264.3         |
|                      | Triticale | 51.9            | 497.2    | 928.2    | 196.7         | 63.2     | 464      | 1133.9   | 246.5         |
| General Mean of      | Wheat     | 48.5            | 463      | 864.5    | 185.1         | 60.1     | 470      | 1192.8   | 252.3         |
| Underground water    | Barely    | 48.9            | 489.6    | 836.2    | 183.4         | 60.9     | 487      | 1321.2   | 268.4         |
|                      | Triticale | 52.4            | 509.1    | 998.7    | 208.7         | 65.2     | 497      | 1394.7   | 307.5         |
| General Mean of      | Wheat     | 50.3            | 498.5    | 896.2    | 195.5         | 63.6     | 493      | 1369.2   | 284.8         |
| Treated waste water  | Barely    | 50.4            | 496.8    | 853.6    | 194.5         | 64.7     | 494      | 1391.6   | 278.4         |
|                      | Triticale | 52.4            | 509.1    | 998.7    | 208.7         | 65.2     | 497      | 1394.7   | 307.5         |
| General Mean of      | Wheat     | 50.3            | 498.5    | 896.2    | 195.5         | 63.6     | 493      | 1369.2   | 284.8         |
| different crops      | Barely    | 50.4            | 496.8    | 853.6    | 194.5         | 64.7     | 494      | 1391.6   | 278.4         |
|                      | Triticale | 52.4            | 509.1    | 998.7    | 208.7         | 65.2     | 497      | 1394.7   | 307.5         |
|                      |           |                 |          |          |               |          |          |          |               |
| LSD for              | Wheat     | 0.64            | 12.4     | 19.8     | 12.4          | 2.4      | 16.7     | 51.4     | 22.8         |
|                      | Barley    | 1.3             | 8.2      | 29.7     | 4.2           | 1.2      | 3.3      | 21.7     | 13.5         |
|                      | Triticale | 1               | 3.4      | 2.3      | 1.8           | 0.5      | 2        | 14.6     | 12.7         |

Effect of magnetic treatments on yield and yield component characters

Significant difference (p<0.05) in the yield and yield component characters among water irrigation treatments were recorded. Much more explicit action of magnetic technology was observed in all yield and yield component parameters for all cereal crops studied. The significant increase was recorded in the grain yield (16.52 %) accompanied by the magnetic water application as compared to irrigation with untreated underground water (Table 6). Özalpan et al. [35] reported similar results where induced magnetic field in water irrigation increased yield and yield parameters of some cereal crops. The mechanisms are not well known yet, the results in this study allowed us to corroborate this increment to increase ions mobility or improve ions uptake under MF treatment (Table 4) which leads to biochemical changes or altered enzyme activities. This might have resulted in better development of photosynthesis stimulation, Dhawi & Al-Khayri [36]. Similar results were reported by Phirek et al. [37]; Aladjadjiyan [38] and Celik et al. [34]. The results presented in Table 6 show that the differences in yield and yield component characters among tested cereal crops were significant (p<0.05). Triticale plant had the highest grain yield value (8.83ton/ha.) and surpassed either wheat (5.57 ton/ha.) or barley (7.69 ton/ha.) grain yields.

Summary

In summary, using magnetic water treatment could be a promising technique for improving agricultural practices by providing sufficient irrigation but extensive research is necessary in order to understand the mechanism of magnetic water action. Therefore, we highly encourage future research efforts focusing on application of this technology for enhanced agricultural practices in water scarce nations. In addition, much efforts are needs to
increase farmer’s awareness that magnetic water technique can assist in saving irrigation water and reducing salt accumulation.

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Table 6: Yield and yield component parameters of cereal crops as affected by irrigation with different water sources (means of two seasons).

| Water Treatment  | Crop   | Yield Component Parameters | Grain Yield /ha | Straw Yield /ha | Biological  |
|------------------|--------|-----------------------------|-----------------|-----------------|-------------|
|                  | No. of spikes m² | Spike length cm | No. of grains /spike | 1000 grain weight g | Grain weight g/m² |
| Magnetic water   | Wheat  | 560 | 7 | 35 | 28.6 | 560 | 5.606 | 3.045 | 8.652 |
|                  | Barley | 574 | 8 | 38 | 29 | 894 | 7.965 | 2.996 | 10.961 |
|                  | Triticale | 585 | 9 | 34 | 29.9 | 925 | 9.3 | 3.762 | 13.062 |
| General Mean of Magnetic Treatment | Wheat | 573 | 8 | 35 | 29.2 | 793 | 7.624 | 3.268 | 10.892 |
|                  | Barley | 524 | 7 | 27 | 27.4 | 678 | 6.79 | 2.543 | 9.333 |
|                  | Triticale | 564 | 8 | 30 | 28.3 | 745 | 7.5 | 3.277 | 10.777 |
| Under-ground water | Wheat | 519 | 6 | 25 | 26.8 | 522 | 5.34 | 4.83 | 7.823 |
|                  | Barley | 524 | 7 | 27 | 27.4 | 678 | 6.79 | 2.543 | 9.333 |
|                  | Triticale | 564 | 8 | 30 | 28.3 | 745 | 7.5 | 3.277 | 10.777 |
| General Mean of under-ground water | Wheat | 535 | 7 | 27 | 27.5 | 648.3 | 6.543 | 2.768 | 9.311 |
|                  | Barley | 551 | 9 | 41 | 29.9 | 925 | 8.33 | 3.2 | 11.53 |
|                  | Triticale | 576 | 9 | 46 | 29.8 | 965 | 9.7 | 3.933 | 13.633 |
| Treated waste water | Wheat | 549 | 8 | 37 | 29.8 | 575 | 5.78 | 3.195 | 8.975 |
|                  | Barley | 551 | 9 | 41 | 29.9 | 925 | 8.33 | 3.2 | 11.53 |
|                  | Triticale | 576 | 9 | 46 | 29.8 | 965 | 9.7 | 3.933 | 13.633 |
| General Mean of Treated waste water | Wheat | 558 | 8.6 | 41 | 29.8 | 821.7 | 7.937 | 3.446 | 11.379 |
|                  | Barley | 549 | 8 | 35.3 | 28.8 | 878.3 | 7.695 | 2.913 | 12.49 |
|                  | Triticale | 575 | 8.7 | 36.6 | 29.3 | 883.3 | 8.333 | 3.657 |
| LSD for          | Water sources | 12.45 | 0.84 | 7.65 | 1.32 | 63.82 | 1 | 0.26 | 1.34 |
|                  | Crop | 22.55 | 0.64 | 2.44 | 0.42 | 66.54 | 1.87 | 0.66 | 2 |
|                  | Interaction | 18.57 | 0.53 | 5.32 | 0.47 | 48.55 | 2.12 | 0.57 | 1.54 |

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