Research Article

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 1000mT 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 12days 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

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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 et al.,[18] The beneficial effects of magnetically treated irrigation water have also been reported on germination percentages by Reina et al.,[11] Reina et al.,[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 et al.,[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 clear 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 method

Plant material, treatments and experimental conditions

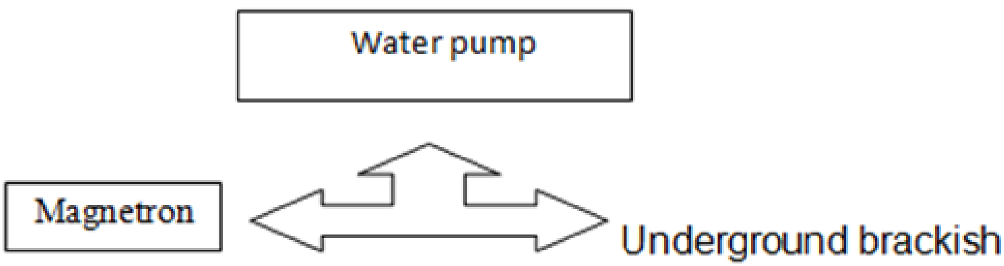
The study was laid out as field experiments in two growing winter seasons of (2009 /2010 and 2010/2011) at the Agricultural Research Station, College of Food and Agriculture Sciences, Derab, Riyadh, King Saud University, Saudi Arabia (24o:42N latitude and 46o:44E Longitudes, Altitude 600m) in a split 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 (1000mT), 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 0-30cm depth from eight sites were collected for soil physical and chemical analyses (Table 1) (Table 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 20cm apart, 3m in length. Plot area was 4.80m^2. To avoid the effect of lateral movement of irrigation water, the strips were isolated by borders of 3meters in width among the sub plots (Figure 1). Grains were sown on the proper sowing date by hand drilled in hills 5 cm apart (approximately five seeds per hill at 2cm depth). All agricultural practices were followed according to the recommendation of extension service.

Data collecting

Grain germination percentage, micronutrients concentration and some growth criteria: Germinating seeds after 6, 9 and 12days from sowing were counted in 3 lines one meter length, and then germination percentage was calculated. Two representative samples were taken during growth (after 45 and 90days from sowing), Three plants from each sub plots were hand pulled randomly for measuring Growth criteria viz., main stem height cm; number of tillers/m^2; fresh and dry weight g/m^2 and dried . Sub samples were also taken for measuring dry matter, and dried in an oven at 700 C for 24hours 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 (m^2) was randomly pulled from two inner center lines of each sub plots to determine grain yield and yield component characters viz., number of spike m^2, spike length cm., number of grains per spike, seed index (weight of 1000 grains) and grain weight per m^2, 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]



Treatment	Magnetizing underground water				Non- magnetizing Underground water				Treated waste water		
	Wheat	Barley	Triticale		Wheat	Barley	Triticale		Wheat	Barley	Triticale
R1				Border zone (3.0 .m)	R1			Border zone (3.m)	R1		
R2					R2				R2		
R3					R3				R3		
R4					R4				R4		

Figure 1 Layout of field experimental design and treatments.

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

Texture	O.M %	$CaCO_3$ %	Physical analysis				Salinity	pH	depth
			Clay %	Silt %	Fine Sand%	Coarse sand %	EC dS/m		
sandy clay loam	0.45	29.9	24	26	15	34.9	15	8.6	0 - 60

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

EC	pH	SAR	Cations (meq/l)				Anions (meq/l)			
dS/m			Ca+	Mg+	Na+	K+	CO3-	HCO3-	Cl-	SO4-
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

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 cross 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 Takatshinko,[8] where magnetic water caused a full germination rate of 100% after 6days from sowing compared to only 83% germination after 9days 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 ions of water molecular which reflected in water properties.[12,21] De Souza et al.,[13] Chang et al.,[27] and Harsharn et al.,[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 Selim MM.[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 $CaCO_3$ and gypsum; this is turn favorably influenced soil pH and resulted higher nutrient uptakes therefore increases their concentrations in the plant tissues.

Regarding to the different among crops, data manifested in the same Table 4 clearly indicated that wheat had the highest values of micronutrients concentrations of Fe, Zn and Mn, followed by triticale and barley. The interaction effects between both factors of magnetizing irrigation water and crops were also significant for micronutrients concentration of Fe, Zn and Mn as compared to either treated waste water or non-magnetizing underground water and crops.

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/m^2; fresh and dry weight g/m^2 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 Shabrangi et al.,[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).

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 et al.,[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 (5.57ton/ha.) or barley (7.69ton/ha.) grain yields.

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	9days	12 days	6 days	9days	12 days
	wheat	21	30	42	35	50	70
Underground brackish water	Barley	24	36	48	40	60	80
	Triticale	34	44	48	57	74	80
General Mean of underground water		26.3	36.7	46	44	61.3	76.6
	wheat	34	42	53	57	70	89
Magnetized water	Barley	36	46	56	60	77	94
	Triticale	39	47	58	65	79	97
General Mean of Magnetic Treatment		36.3	45	55.7	61	75.33	93.3
	wheat	28	36	48	47	60	80
Treated waste water	Barley	33	42	52	55	70	87
	Triticale	35	45	56	59	75	93
General Mean of Treated waste water		32	41	52	54	68.33	86
General Mean of different crops							
Wheat		27.67	36	47.67	46	60	79.7
Barley		31	41.33	52	52	69	87
Triticale		36	45.33	54	60	76	90

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

Water treatment	Crop	Micro nutrient concentration (ppm)		
		Fe	Zn	Mn
	Wheat	178	88	65
Magnetic water	Barely	174	79	67
	Triticale	170	80	67
General Mean of Magnetic Treatment		174	82.3	66.3
	Wheat	162	70	57
Under-ground water	Barely	140	72	60
	Triticale	144	73	58
General Mean of under-ground water		148.6	71.7	58.3
	Wheat	169	77	62
Treated waste water	Barely	158	73	66
	Triticale	164	76	65
General Mean of Treated waste water		163.7	75.3	64.3
General Mean of different crop				
Wheat		169.7	78.3	64.3
Barley		157.3	74.7	61.3
Triticale		159.3	76.3	63.3

Table 5 Growth characters at different growth stages of cereal crops as affected by sources of water

Water Treatment	Crop	Tillering stage				Heading stage			
		Main stem height cm	No. of tillers/m2	Freshweightg/m2	Dryweightg/m2	Main stem height cm	No. of tillers/m2	Weigh tg/m2	Dry weightg/ m2
	Wheat	49.9	475.6	849.4	186.9	61.5	484	1240.2	268.6
Magnetic water	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 Magnetic Treatment		51.1	483.2	865.8	191	62.7	488	1248.4	279
	Wheat	45.6	437.4	840.8	180.2	59.7	467	1214	246.2
Under-ground water	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 underground water		48.5	463	864.5	185.1	60.1	470	1192.8	252.3
	Wheat	48.9	489.6	836.2	183.4	60.9	487	1321.2	268.4
Treated waste water	Barely	50.3	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 Treated waste water		50.3	498.5	896.2	195.5	63.6	493	1369.2	284.8

Table Continued

Water Treatment	Crop	Tillering stage				Heading stage			
		Main stem height cm	No. of tillers/m2	Freshweightg/m2	Dryweightg/m2	Main stem height cm	No. of tillers/m2	Weigh tg/m2	Dry weightg/ m2
Wheat		48.1	467.5	842.1	183.5	60.7	479	1258.5	261.1
Barley		49.6	476.5	842.1	186.8	62.5	487	1289.7	274.1
Triticale		52.4	500.6	942.2	201.3	64.2	484	1262.3	289.9
LSD for									
Water sources		0.64	12.4	19.8	12.4	2.4	16.7	51.4	22.8
Crop		1.3	8.2	29.7	4.2	1.2	3.3	21.7	13.5
Interaction		1	3.4	2.3	1.8	0.5	2	14.6	12.7

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							
		No. of spikes m2	Spike length cm	No. of grains / spike	1000 grain weight g	Grain weight g/m2	Grain Yield ton/ha	Straw Yield ton/ha	Biological
Magnetic water	Wheat	560	7	35	28.6	560	5.606	3.045	8.652
	Barely	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		573	8	35	29.2	793	7.624	3.268	10.892
Under-ground water	Wheat	519	6	25	26.8	522	5.34	2.483	7.823
	Barely	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		535	7	27	27.5	648.3	6.543	2.768	9.311
Treated waste water	Wheat	*549*	8	37	29.8	575	5.78	3.195	8.975
	Barely	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		558	8.6	41	29.8	821.7	7.937	3.446	11.379
General Mean of different crops						552			8.48
Wheat		542	7	32.3	28.4	832.3	5.575	2.908	10.61
Barley		549	8	35.3	28.8	878.3	7.695	2.913	12.49
Triticale		575	8. 7	36.6	29. 3		8.833	3.657	
LSD for		12.45	0.84	7.65	1.32	63.82	1	0.26	1.34
Water sources		22.55	0.64	2.44	0.42	66.54	1.87	0.66	2
Crop		18.57	0.53	5.32	0.47	48.55	2.12	0.57	1.54
Interaction									

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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Conflict of interest

The author declares no conflict of interest.

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