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Magnetic effect on chemical properties of saline waters

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Abstract
Magnetic force has been used in different field of science it offers many benefits. Now days, magnetic device use in agriculture is getting increased for field experience of better crop growth and development with the magnetized water without much scientific evidence. In this regard, a laboratory experiment was conducted for assessing effect of magnetism on chemical properties of saline water. Water with different salinity levels *viz.* S1 (0.5 dS m^{-1}), S2 (2.0 dS m^{-1}), S3 (4.0 dS m^{-1}), S4 (6.0 dS m^{-1} and S5 (8.0 dS m^{-1}) were exposed to magnetic strength *viz.* 0.18 Tesla (T), 0.29 T and 0.44 T under the south pole and north pole orientations over varied duration *viz.* two minutes, four minutes and six minutes. The electrical conductivities of saline water decreased significantly with increase of magnetic field strength and duration of exposure but the effects size were in reverse trend including for water salinity. The significantly and relatively high reduction of saline waters electrical conductivity value was recorded under the South Pole orientations. The 0.44 T magnetic field for six minutes exposure of saline waters recorded high EC decline which was 54 %, 31 % and 17.6 % respectively in the 0.5 dS m^{-1}, 2 dS m^{-1} and 4.0 dS m-1 saline waters. The persistency of magnetic effect for saline waters found to be differed significantly for magnetic orientation. The low saline water up to 2 dS m^{-1} had the high persistency period of 5 days in South Pole while it was two days under North Pole. Moreover, the 4.0 dS m^{-1} saline water had two days more persistency under South Pole. The magnetic field did not bring any significant changes on saline water pH, cationic and anionic concentration. The magnetic field can be effectively used for bringing significant change in the electrical conductivity properties of saline waters up to 4 dS m^{-1}. However, further research on magnetic field based water structural modification derived memory lasting and the magnetized saline water interaction with soils and eventually the crop performance need to be investigated.

Keywords: magnetic fields saline waters, electrical conductivity, water treatment, exposure durations magnetic orientations

Introduction
Magnetic field has been an emerging physical technique in agriculture and other branch of science without much of scientific evidence. Magnetic device use in agriculture getting increased with field experience of better crop growth and development if magnetically treated water used for agriculture and subsequently different kinds of magnetizer started to appear in the market. On other side, even though research on magnetic field has been continued to explore since later period of nineteenth century, understanding of magnetic field effects during and after the treatment of water and aqueous solution is a controversial issue as there is no clear indication of how the magnetic field interacts with matters (Funce and cabell, 1890) [10]. Recently, many research papers published on magnetic field interaction with water and aqueous solution (Tijing *et al*., 2014; Ghernout, 2018) [22].
The magnetic field study originally started addressing hard scale formation and their effect on conveyance installed in large scale industries. In this regard, magnetic field based different chemical reactions on mineral precipitation were explained (Sammer *et al*. 2016) [19]. Magnetic field not only affects the ions and molecules present in solution but also nature of different surface nuclei and particles already present in water (Saksono *et al*., 2008) [18]. The magnetic field induces quick transfer of protons from hydrogen carbonate to water thereby affects association ions and nucleation process. Aragonite is a polymorphism of carbonate shows less adhesive that found large proportion over calcium carbonate in magnetically treated solution support the reduced scale formation in the conveyance. For instance, the magnetized sodium carbonate solution (0.3T) showed a reduced hard scale size with large proportion of aragonite precipitation (Lundader Madsen, 1995; Cefalas *et al*., 2010) [5, 16, 17]. Exposure of 0.5 M nitrates of Ba, Sr, Ca and Ag solution, sodium sulphate, sodium chloride to 1 T(Tesla) magnetic field revealed that not only divalent cations, the divalent anions are more susceptible for magnetic

fields. The precipitated $SrSO_4$ remain stable in the solution more than two days (Silva *et al*., 2015) [20]. The calcium carbonate precipitation reaction even reported for exposure to a low 0.16 T highly regulated by the hydration of magnesium, iron and sulphate ions that can be indicated by the zeta potential change of ions (Holysz *et al*., 2003; Alimi *et al*., 2009) [14, 21]. Development of different polymorphisms of carbonate under magnetic field are explained by the mechanism of cluster transformation thereby the hydrogen bond strength getting increased and weakened respectively in the intra cluster and inter clusters of water. The physical structure of water changed for exposure of water to magnetic field (0-10 T) for increase of hydrogen bonds (0.34%) which resulted in decreased ion self-diffusion co-efficient and increased water viscosity (Chang and Weng 2006) [6]. The magnetic field accelerates Lorentz force which causes mobility of ions against ion-water interaction that favors nucleation and precipitation process (Wang *et al*. 2012; Guo *et al*. 2011) [6, 13]. Recently, it was revealed the formation of dynamically ordered liquid like oxyanion polymers (DOLLOP) under magnetic field explained for precipitation of ions, which are considered a pre-nucleation cluster can participate not only the precipitation of carbonate but also for other anions under ambient situations (Coey *et al*. 2012) [8]. On the same way of ions and molecules responded, water molecules treated under the magnetic fields of 0.33 T-0.29 T has shown 24% decreased surface tension and 42% decreased evaporation over the control at 80 ºC. Cai *et al.* (2009) [4] found the viscosity of water get increased when water passed at constant flow rate of 1 ml s^{-1} under the magnetic field of 0.5T.

These are evidences for magnetic field associated change of water physicochemical properties. However, there is no much of study have so far accounted the change of composition of solution and other chemical properties. The hypothesis of the present study was that magnetic field-assisted nucleation and precipitation brings changes in the chemical composition such as cations (Ca^{2+}, Mg^{2+}, Na^+) and anions (Cl^-, SO_4^{2-} and HCO_3) concentrations as well as the pH and electrical conductivity of saline water.

Materials and Methods

Fabrication of magnetic device

This is a portable device that can be used to import magnetism to water and any other materials under lab conditions by exposing to designed conditions of magnetic field strength and exposure time. It was necessary to fabricate device which can create heterogeneous magnetic field since there is no device available to import magnetism. This prototype fabricated with pre-determined scale consisted of frame, motor, shaft, magnet, round plate, base plate, top cover sheet and bottle mount that all joined appropriately together in making of the compact laboratory apparatus, the magnetic device (Figure 1).

Frame

It is made up with iron material. The top portion of the frame made more specious with the physical dimension of 63.3 cm wide and 53.3 cm length so that it could facilitate handling of water samples. The device had height of 72.3 cm frame from the ground surface. Concerning device vibration from running motor, there were two reinforcements fixed just under the top portion of main frame for holding the motor.

Shaft

It is used to connect the running motor and based plate along with round plate. The length of shaft is 14.5 cm, of which 3 cm height of soft protruded just above the frame to hold the base plate and 7.5 cm length extended down through the frame to 0.5 hp motor.

a) Full view of magnetizer

b) Top view of magnetizer

Fig 1: Prototype of magnetic device

Magnet

There were six large size commercially available magnets used for experiments. The dimension of magnet is 15 cm length, 2.5 cm breadth and 10 cm wide.

Magnetic cover

It is a packet configuration made up from stainless steel since it does not gets attracted by magnetic force. The dimension of magnet cover is 15.4 cm length and 10.5 cm wide and 3 cm breadth. From the center point to the top portion of cover, the V shape opening at 3 cm length. It facilitates easy handling of large size magnets as well as hold the magnets during experimentation.

Round plate

It is almost same dimension of round plate placed just below the round plate connecting with shaft.

Base plate

It is rotating plate on which the six magnetic covers welded so tight that it could not come out while the plate in angular motion. The diameter of rotating plate is 29 cm.

Bottle-mount/sample holder

It is made up from stainless steel has three arms fixed with the main frame. It is a circular shape sample holder has 20 cm diameter and the sample is being kept at center within 10 cm diameter circle. At a time we can able to treat water sample capacity of two liters with changing treatment variables.

For kinetic motion of magnets, 0.5 HP motor is fixed under the table with the facility of pre-determined automation settings. It can be also equipped with display panel for presetting and actual values for time duration and the kinetic revolution of motor per minute.

The heterogeneous magnetic field of device created with different kinds of commercially available magnets of above mentioned size at kinetic motion nearly at 450 rpm. The fields were recorded at 5 cm, 10 cm and 15 cm away from magnets using magnetic meter (Model: MG-3002), which had provision of sensor probe for automatic adjustment of magnetic fields value for changing room temperature conditions. Since, the fields recorded were heterogeneous nature, average value of fields used just as notion and description purpose (refer Table 1).

Table 1: Magnetic fields recorded at 5 cm, 10 cm and 15 cm away from magnets at 450 rpm motor conditions

Magnetic fields	Magnets	Magnetic field (Tesla)		
		5 cm	10 cm	15 cm
M1 at 0.18 T	Magnet-1	0.30	0.15	0.13
	Magnet-2	0.27	0.15	0.15
	Magnet-3	0.24	0.08	0.07
	Magnet-4	0.33	0.25	0.24
	Magnet-5	0.24	0.14	0.14
	Magnet-6	0.26	0.11	0.05
M2 at 0.29 T	Magnet-1	0.41	0.22	0.16
	Magnet-2	0.49	0.31	0.26
	Magnet-3	0.37	0.18	0.15
	Magnet-4	0.50	0.32	0.27
	Magnet-5	0.39	0.16	0.11
	Magnet-6	0.46	0.21	0.23
M3 at 0.44 T	Magnet-1	0.62	0.31	0.18
	Magnet-2	0.72	0.31	0.31
	Magnet-3	0.66	0.29	0.25
	Magnet-4	0.60	0.47	0.43
	Magnet-5	0.70	0.4	0.37
	Magnet-6	0.70	0.33	0.21

Synthesis of saline waters

To represent stipulation of saline water criteria at 1:1 ratio of chloride and sulphate, saline waters prepared from salt mixtures following the procedure given by Hussain *et al.* (1985). Accordingly, 2.009 g of sodium chloride (NaCl), 2.996 g of sodium sulphate (Na2SO4), 1.15 g of calcium chloride dehydrate (CaCl2.2H2O) and 0.961 g of magnesium sulphate heptahydrate (MgSO4. 7H2O) dissolved in 5000 ml of distilled water in order to have the solution conductivity value 2.0 dS m-1. Following the same procedure, required quantity of salts for the saline waters of 4.0, 6.0 and 8.0 dS m-1 calculated and prepared using distilled water in the laboratory. The conductivity values of salt solution were 2.18 dS m-1, 4.19 dS m-1, 6.22 dS m-1 and 8.08 dS m-1.

Experimental procedures

A 50 ml of respective saline waters taken in the 100 ml shaking bottle kept in the sample holder which made with provision of nest at the center of device. The device was constantly operated at arbitrate number 450 rpm for the purpose of creating very efficient non-homogenous gradient magnetic field. The saline waters samples were exposed to North Pole and South Pole magnetic orientations at appropriate combination of magnetic fields (0.18 T, 0.29 T and 0.44 T) and exposures durations (Two minutes, Four minutes and Six minutes). The treated waters subjected to evaluation of pH, electrical conductivity (dS m-1), cations (meq L-1) of calcium, magnesium and sodium, and anions (meq L-1) of chloride, sulphate and bicarbonate ions. The effect on different water properties lasted over a period of time after cessation of magnetic field referred as "memory effect". It is important to know whether the altered electrical conductivity of saline waters exposed to the 0.44 T magnetic fields over the six minutes duration remain stable or transitory nature. In this regard, saline waters electrical conductivities after the cessation of exposure to magnetic field 0.44 T and six minutes durations measured repeatedly at immediately after exposure, two days after cease of magnetic field and five days. The per cent decline of EC in comparison with before exposure magnetic fields was compared to elucidate the transitory nature of effect.

Results and Discussion

Magnetic field effect on electrical conductivity of saline waters

The salt content of water is indicated implicitly by the Electrical conductivity value. The declining of electrical conductivity value of saline water was observed with increase of magnetic field, exposure duration and salt content of water but the reverse trend was observed regarding rate of change was declined with increase of magnetic field (Table 2). The EC value reduction in the 0.5 dS m-1, low saline water was high and they were 50.5 % and 64 % reduction in the north and South Pole, respectively. The 0.49 T magnetic field and six minutes duration had a higher EC decline at 14.8 % in the North Pole and 18.1 % decline in the South Pole which was on par with four minutes exposure duration under the same 0.49 T magnetic field. However, the magnetic treatments based EC decline was highly specific saline waters that the 0.5 dS m-1 saline water exposed to 0.49 T magnetic field and six minutes duration recorded a higher decline of 64%.

The EC declining efficiency for saline water exposure to magnetic field was in the range of 2 to 64 per cent and the declining efficiency was higher for exposure to South Pole magnetic orientation and it was decreased with increase of saline water EC value. The relatively higher declining efficiency was around 10.5 to 13.5 %, 4 to 5.6 %, 2.2 to 3.7%, 1.6 to 3.3 % and 1.3 to 1.84% in the 0.5, 2.0, 4.0, 6.0 and 8.0 dS m-1 saline waters, respectively. Bartusek *et al.* 2017 [3] verified structure of liquid water change under the spiral gradient magnetic field highly associated with decline of electrical conductivity property of demineralised water. The decline was around 50 % over the control treatment for exposure period of five minutes. It is further suggested that the ions inducing the water conductivity may become more closely bound to the cluster structure of the molecules due to magnetic field gradient established through creation of heterogeneous magnetic field. In contrast, the static magnetic field increased the electrical conductivity of distilled as well as electrolyte solution for various exposure period (Levchuk and Levin, 2015) [15]. The waves from South Pole of magnets had more interactive effect that had relatively large effect on EC value of saline waters over the North Pole as the results be expected.

Magnetic field effect on saline waters cations and anions concentration

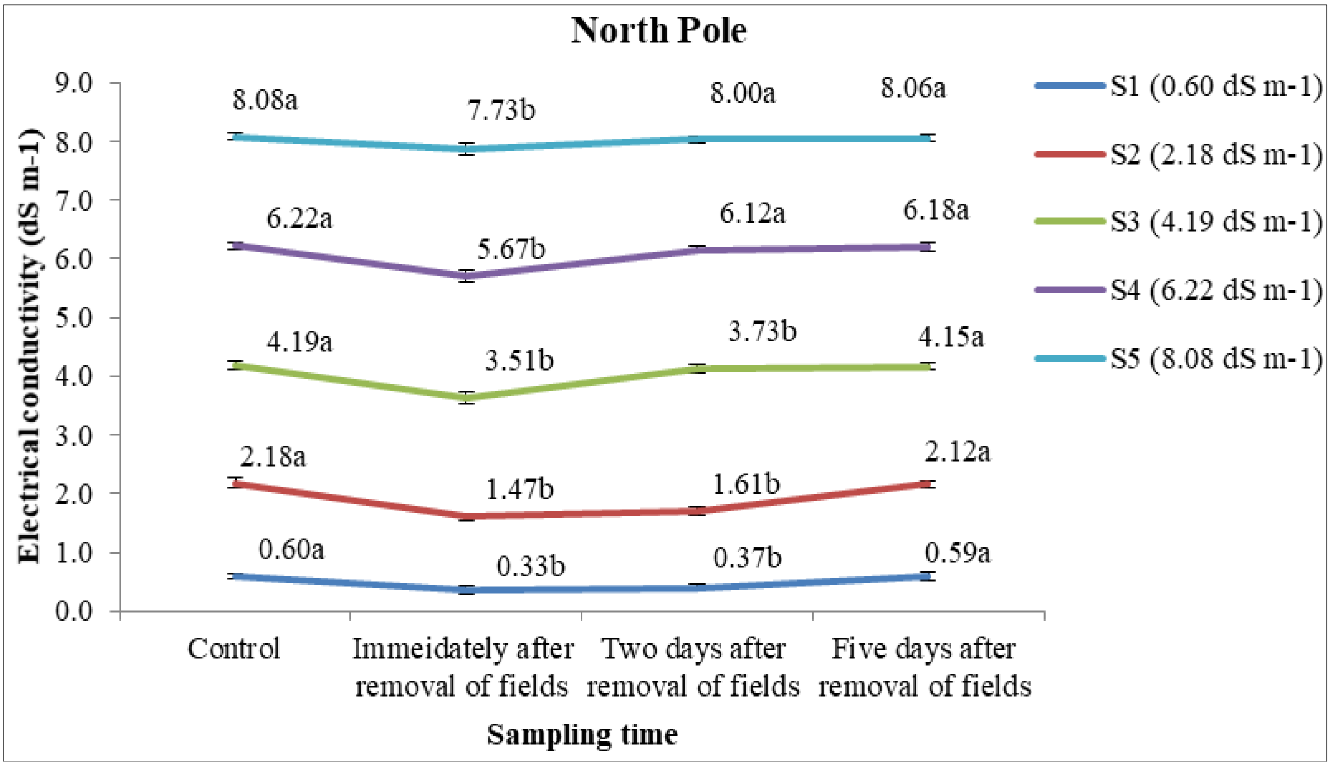
The cations such as Ca2+, Mg2+, Na+ and anions such as Cl-, SO42- and HCO3- were more closely associated with electrical conductivity of saline waters. The calcium concentrations were 0.45, 1.85, 3.71, 5.55 and 8.40 meq L-1 in the S1, S2, S3, S4 and S5 saline waters, respectively. Similarly, the magnesium and sodium ions concentrations were 0.34, 1.35, 2.71, 4.05 and 6.61 meq L-1 and 3.83, 13.60, 27.18, 40.80 and 56.20 meq L-1 in the S1, S2, S3, S4 and S5 saline waters, respectively. The chloride and sulphate anions concentration were 2.43, 9.70, 19.40, 29.10 and 38.8 meq L-1 and 1.28, 5.20, 10.40, 15.60 and 20.80 and 41.56 meq L-1 in the S1, S2, S3, S4 and S5 saline waters, respectively. Even though the electrical conductivity value decreased for exposure to heterogeneous magnetic field strength but the cations and anions concentration of saline water did not get affected by magnetic fields (Table 3, 4, 5, 6, 7 & 8). Similarly, the pH of saline water was also not get influenced for exposure to magnetic fields (Table 3).

Memory effect of saline water electrical conductivity

Based on per cent EC decline over the period of five days after cease of magnetic field exposure, the persistency of effect was studied for saline waters at the interval of one day, two days and five days in both south and north poles. It was found that the consistency of memory effect was decreasing with increase of salt content under the both poles. The relatively high persistency EC value over the period of five days was observed in the low saline water 0.5 dS m-1 (S1) which had maintained the declined EC value around 30.5 % of the control under North Pole and 38.7 % under the South Pole. The 17.8 % of the 2.00 dS m-1 saline water EC value under North Pole and 22 % under South Pole was still observed 5 days after cease of magnetic field.

The time of observation effect on persistence of declined EC value studied after saline water removed from the magnetic treatment of 0.44 T field and six minutes duration. It was found that the EC value started to rebound to original level. The magnetic effect on EC was maintained around 10.5 % decline at time of immediately after the removal of treatment and it was decreased with time. The similar trend was also observed for South Pole but had relative high persistency.

For the interactive effect of saline water, magnetic orientation and extend of period after the field removal, it was found that the maximum persistence of EC value was maintained up to two days after removal of fields exposure in both of the saline waters S1 (0.63 dS m-1) and S2 (2.18 dS m-1). The persistent effect was recorded around 40 % and 24 % EC decline under South Pole over that of respective saline waters EC value before exposed to field. Under South Pole, the maintained effect was significant even for five days for recording 6% and 3% of control treatment EC value. The magnetic effect was even persisted for 4.0 dS m-1 saline water up to two days recording 11.5 % EC value decline under South Pole. The remaining saline waters rebounded very quickly that it had just one per cent that of original EC value. The memory effect for different physiochemical properties of water and solution varied from seconds to few days (Szczes *et al*., 2011; Silva *et al*., 2015) [20, 21]. The infrared absorption property of magnetized water found increase with increase of magnetic field which have lasted the maximum of 60 minutes durations. Since, mineral components of water have quick relaxation over hydrogen ions that the memory effect decreased with increase of salt content (Colic & Morse, 1999) [9]. The memory effect also enhanced for formation gas substances and reactive oxygen species promotes clathrate structures of water which significantly increase the memory effects of water (Colic and Morse, 1999) [9]. It was new findings that South Pole had a greater memory effect over North Pole. This was as per the expectation since the force comes from South Pole had relatively a greater force might have caused more memory effect.



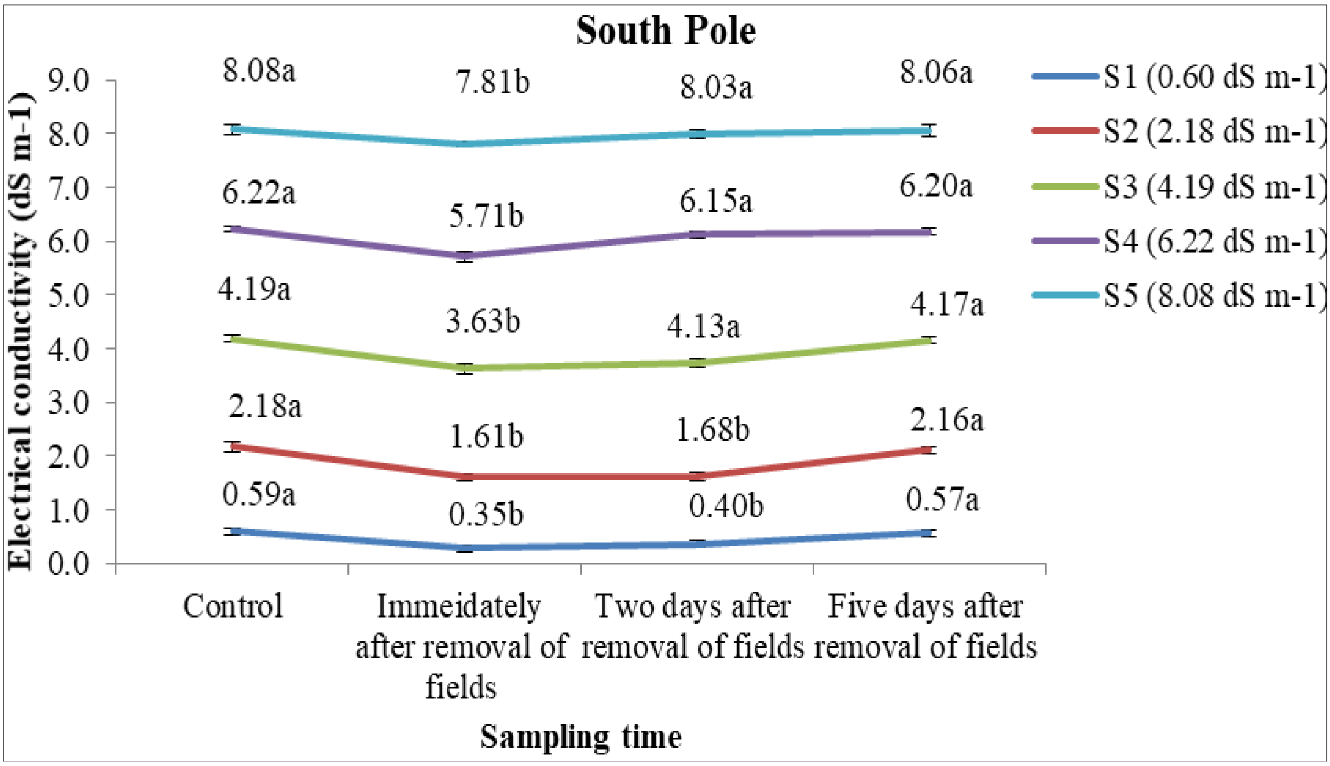


Fig 6: The electrical conductivity consistency of saline waters after cessation of magnetic field exposure to 0.44 T magnetic field for six minutes duration under the north pole and south pole magnetic orientations

Table 2: Effect of magnetic fields exposure on electrical conductivities (dS m^{-1}) of synthesized salt waters

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean
T_1-Control	0.50	2.00	4.00	6.00	8.00	4.10	0.50	2.00	4.00	5.98	8.00	4.09
T_2-0.18T MF + Two minutes ED	0.46 (8.00)	1.90 (5.00)	3.77 (5.81)	5.88 (2.08)	7.91 (1.19)	3.97 (2.23)	0.40 (20.0)	1.82 (9.00)	3.68 (8.00)	5.78 (3.67)	7.80 (2.50)	3.88 (4.69)
T_3-0.18T MF + Four minutes ED	0.45 (11.00)	1.87 (6.37)	3.71 (7.31)	5.84 (2.50)	7.88 (1.56)	3.94 (2.93)	0.39 (23.0)	1.79 (10.50)	3.60 (10.00)	5.72 (4.67)	7.75 (3.13)	3.84 (5.19)
T_4-0.18T MF + Six minutes ED	0.39 (23.00)	1.78 (11.12)	3.66 (8.62)	5.75 (4.21)	7.84 (2.06)	3.86 (5.81)	0.32 (36.00)	1.69 (15.50)	3.53 (11.75)	5.63 (6.25)	7.70 (3.75)	3.75 (8.88)
T_5-0.29T MF + Two minutes ED	0.46 (8.50)	1.85 (7.75)	3.72 (7.12)	5.77 (3.92)	7.84 (2.03)	3.90 (2.38)	0.40 (19.50)	1.76 (12.0)	3.61 (9.75)	5.65 (5.83)	7.72 (3.50)	3.81 (5.11)
T_6-0.29T MF + Four minutes ED	0.39 (22.00)	1.73 (13.75)	3.62 (9.56)	5.66 (5.62)	7.79 (2.59)	3.82 (5.73)	0.33 (34.5)	1.63 (18.50)	3.50 (12.63)	5.54 (7.67)	7.66 (4.25)	8.79 (11.79)
T_7-0.29T MF + Six minutes ED	0.34 (31.50)	1.68 (16.12)	3.48 (13.06)	5.66 (5.71)	7.78 (2.81)	3.77 (7.98)	0.28 (44.6)	1.57 (21.50)	3.35 (16.25)	5.53 (7.83)	7.63 (4.63)	3.65 (11.27)
T_8-0.44T MF + Two minutes ED	0.42 (16.50)	1.75 (12.37)	3.69 (7.81)	5.69 (5.25)	7.80 (2.53)	3.85 (4.43)	0.36 (28.00)	1.66 (17.00)	3.57 (10.75)	5.56 (7.33)	7.68 (4.00)	3.75 (7.27)
T_9-0.44T MF + Four minutes ED	0.35 (31.00)	1.58 (21.12)	3.55 (11.37)	5.56 (7.42)	7.76 (2.97)	3.74 (9.03)	0.28 (44.20)	1.47 (26.00)	3.42 (14.63)	5.40 (9.67)	7.62 (4.75)	3.62 (12.32)
T_{10}-0.44T MF + Six minutes ED	0.30 (40.50)	1.48 (25.87)	3.44 (14.06)	5.49 (8.50)	7.73 (3.41)	3.67 (11.77)	0.23 (54.00)	1.37 (31.50)	3.29 (17.75)	5.35 (10.83)	7.58 (5.25)	3.54 (15.11)
Mean	0.40 (21.38)	1.76 (13.28)	3.66 (9.42)	5.73 (5.02)	7.83 (2.35)		0.35 (34.03)	1.68 (18.00)	3.55 (12.39)	5.62 (6.99)	7.71 (3.97)	
	Saline waters (W)		Treatments (T)		WXT		Saline waters (W)		Treatments (T)		WXT	
SEd	7.00		5.6		5.1		6.65		4.50		4.75	
CD (5%)	14.00		11.2		10.2		13.31		9.12		9.5	

MF- Magnetic field strength; ED- Exposure duration; Values in parenthesis are percentage decline over the control used for anova analysis and CD value calculation

Table 3: Effect of magnetic fields exposure on pH of synthesized salt waters

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.6)	S2 (2.18)	S3 (4.19)	S4 (6.22)	S5 (8.08)	Mean	S1 (0.6)	S2 (2.18)	S3 (4.19)	S4 (6.22)	S5 (8.08)	Mean
T1-Control	7.74	7.74	7.71	7.70	7.70	7.72	7.74	7.74	7.71	7.70	7.70	7.72
T2-0.18T MF + Two minutes ED	7.72	7.73	7.76	7.75	7.75	7.74	7.71	7.73	7.75	7.77	7.76	7.74
T3-0.18T MF + Four minutes ED	7.70	7.72	7.75	7.73	7.74	7.73	7.70	7.72	7.74	7.76	7.73	7.73
T4-0.18T MF + Six minutes ED	7.69	7.70	7.74	7.71	7.72	7.71	7.68	7.70	7.72	7.74	7.72	7.71
T5-0.29T MF + Two minutes ED	7.72	7.72	7.75	7.73	7.74	7.73	7.71	7.72	7.74	7.76	7.73	7.73
T6-0.29T MF + Four minutes ED	7.70	7.72	7.73	7.72	7.72	7.72	7.69	7.72	7.69	7.71	7.73	7.71
T7-0.29T MF + Six minutes ED	7.69	7.70	7.69	7.71	7.68	7.69	7.68	7.70	7.67	7.69	7.72	7.69
T8-0.44T MF + Two minutes ED	7.71	7.71	7.73	7.72	7.73	7.72	7.70	7.71	7.71	7.73	7.72	7.71
T9-0.44T MF + Four minutes ED	7.69	7.70	7.72	7.71	7.71	7.70	7.68	7.69	7.70	7.72	7.71	7.70
T10-0.44T MF + Six minutes ED	7.69	7.70	7.71	7.69	7.69	7.69	7.72	7.72	7.70	7.70	7.71	7.71
Mean	7.70	7.71	7.73	7.72	7.72		7.70	7.71	7.71	7.73	7.72	
	Saline waters (S)		Treatments (T)		SXT		Saline waters (S)		Treatments (T)		SXT	
SEd	0.11		0.12		0.09		0.17		0.13		0.13	
CD (5 %)	NS		NS		NS		NS		NS		NS	

Table 4: Effect of magnetic fields exposure on calcium concentration (meq L^{-1}) of synthesized salt waters

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean
T_1-Control	0.45	1.85	3.71	5.55	8.40	2.89	0.45	1.85	3.71	5.55	8.40	2.89
T_2-0.18T MF + Two minutes ED	0.44	1.85	3.70	5.55	8.39	2.89	0.43	1.85	3.70	5.54	8.39	2.88
	(2.22)	(0.14)	(0.20)	(0.00)	(0.12)	(0.54)	(4.44)	(0.14)	(0.20)	(0.18)	(0.12)	(1.02)
T_3-0.18T MF + Four minutes ED	0.44	1.84	3.69	5.54	8.38	2.88	0.44	1.84	3.69	5.55	8.38	2.88
	(2.22)	(0.68)	(0.54)	(0.14)	(0.12)	(0.74)	(2.22)	(0.68)	(0.54)	(0.00)	(0.12)	(0.71)
T_4-0.18T MF + Six minutes ED	0.44	1.83	3.70	5.53	8.36	2.88	0.45	1.83	3.70	5.54	8.39	2.88
	(2.22)	(0.81)	(0.27)	(0.36)	(0.12)	(0.76)	(0.00)	(0.81)	(0.27)	(0.18)	(0.12)	(0.28)
T_5-0.29T MF + Two minutes ED	0.45	1.84	3.71	5.54	8.38	2.89	0.44	1.84	3.70	5.54	8.38	2.88
	(0.00)	(0.54)	(0.00)	(0.18)	(0.12)	(0.17)	(2.22)	(0.54)	(0.27)	(0.18)	(0.12)	(0.67)
T_6-0.29T MF + Four minutes ED	0.44	1.83	3.69	5.53	8.39	2.87	0.43	1.83	3.69	5.55	8.39	2.88
	(2.22)	(0.95)	(0.54)	(0.45)	(0.12)	(0.86)	(4.44)	(0.95)	(0.54)	(0.00)	(0.12)	(1.21)
T_7-0.29T MF + Six minutes ED	0.43	1.82	3.70	5.54	8.36	2.87	0.45	1.82	3.70	5.55	8.37	2.88
	(4.44)	(1.49)	(0.27)	(0.18)	(0.12)	(1.30)	(0.00)	(1.49)	(0.27)	(0.00)	(0.12)	(0.38)
T_8-0.44T MF + Two minutes ED	0.45	1.83	3.71	5.54	8.36	2.88	0.45	1.83	3.71	5.54	8.38	2.88
	(0.00)	(1.22)	(0.00)	(0.18)	(0.12)	(0.30)	(0.00)	(1.22)	(0.00)	(0.18)	(0.12)	(0.30)
T_9-0.44T MF + Four minutes ED	0.44	1.84	3.69	5.53	8.37	2.88	0.44	1.80	3.70	5.54	8.40	2.87
	(2.22)	(0.54)	(0.54)	(0.36)	(0.12)	(0.76)	(2.22)	(2.43)	(0.27)	(0.18)	(0.12)	(1.04)
T_{10}-0.44T MF + Six minutes ED	0.43	1.82	3.70	5.53	8.37	2.87	0.43	1.83	3.69	5.53	8.38	2.87
	(4.44)	(1.62)	(0.27)	(0.36)	(0.12)	(1.36)	((4.44)	(1.08)	(0.54)	(0.36)	(0.12)	(1.31)
Mean	0.44	1.84	3.70	5.54	8.38		0.44	1.83	3.70	5.54	8.39	
	(2.22)	(0.89)	(0.29)	(0.25)	(0.12)		(2.22)	(1.04)	(0.32)	(0.14)	(0.12)	
	Saline waters (S)		Treatments (T)		SXT		Saline waters (S)		Treatments (T)		SXT	
SEd	1.75		1.00		0.80		1.64		0.97		0.75	
CD (5%)	NS		NS		NS		NS		NS		NS	

MF- Magnetic field strength; ED- Exposure duration; Values in parenthesis are percentage decline over the control used for ANOVA analysis and CD value calculation

Table 5: Effect of magnetic fields exposure on magnesium concentration (meq L^{-1}) of synthesized salt waters (Mean of the four replication values)

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean
T_1-Control	0.34	1.35	2.71	4.05	6.61	5.85	0.34	1.35	2.71	4.05	6.61	5.85
T_2-0.18T MF + Two minutes ED	0.34	1.35	2.70	4.04	6.61	5.85	0.34	1.35	2.71	4.04	6.60	5.85
	(0.00)	(0.00)	(0.37)	(0.25)	(0.00)	(0.12)	(0.00)	(0.00)	(0.00)	(0.25)	(0.15)	(0.08)
T_3-0.18T MF + Four minutes ED	0.34	1.34	2.70	4.04	6.60	5.84	0.33	1.34	2.70	4.04	6.60	5.84
	(0.00)	(0.74)	(0.37)	(0.25)	(0.15)	(0.30)	(2.94)	(0.74)	(0.37)	(0.25)	(0.15)	(0.89)
T_4-0.18T MF + Six minutes ED	0.33	1.34	2.69	4.03	6.59	5.84	0.33	1.34	2.70	4.03	6.59	5.84
	(2.94)	(0.74)	(0.74)	(0.49)	(0.30)	(1.04)	(2.94)	(0.74)	(0.37)	(0.49)	(0.30)	(0.97)
T_5-0.29T MF + Two minutes ED	0.34	1.34	2.70	4.04	6.60	5.85	0.33	1.34	2.70	4.04	6.59	5.84
	(0.00)	(0.74)	(0.37)	(0.25)	(0.15)	(0.30)	(2.94)	(0.74)	(0.37)	(0.25)	(0.30)	(0.92)
T_6-0.29T MF + Four minutes ED	0.34	1.33	2.69	4.03	6.60	5.84	0.34	1.33	2.69	4.03	6.59	5.84

	(0.00)	(1.48)	(0.74)	(0.49)	(0.15)	(0.57)	(0.88)	(1.48)	(0.74)	(0.49)	(0.30)	(0.78)
T_7-0.29T MF + Six minutes ED	0.33	1.33	2.69	4.03	6.59	5.84	0.33	1.33	2.69	4.03	6.58	5.83
	(2.94)	(1.48)	(0.74)	(0.49)	(0.30)	(1.19)	(2.94)	(1.48)	(0.74)	(0.49)	(0.45)	(1.22)
T_8-0.44T MF + Two minutes ED	0.33	1.33	2.70	4.03	6.59	5.84	0.33	1.33	2.70	4.03	6.59	5.83
	(3.24)	(1.48)	(0.37)	(0.49)	(0.30)	(1.18)	(3.82)	(1.48)	(0.37)	(0.49)	(0.30)	(1.29)
T_9-0.44T MF + Four minutes ED	0.33	1.33	2.69	4.02	6.59	5.83	0.33	1.32	2.69	4.02	6.58	5.83
	(3.53)	(1.48)	(0.74)	(0.74)	(0.30)	(1.36)	(2.94)	(2.22)	(0.74)	(0.74)	(0.45)	(1.42)
T_{10}-0.44T MF + Six minutes ED	0.33	1.33	2.68	4.02	6.58	5.83	0.33	1.32	2.68	4.02	6.57	5.82
	(3.82)	(1.48)	(1.11)	(0.74)	(0.45)	(1.52)	(2.94)	(2.22)	(1.11)	(0.74)	(0.61)	(1.52)
Mean	0.33	1.34	2.70	4.03	6.60		0.33	1.34	2.70	4.03	6.59	
	(1.83)	(1.07)	(0.62)	(0.47)	(0.24)		(2.48)	(1.23)	(0.53)	(0.47)	(0.34)	
	Saline waters (S)		Treatments (T)		SXT		Saline waters (S)		Treatments (T)		SXT	
SEd	1.52		1.2		0.94		1.4		1.11		0.87	
CD (5 %)	NS		NS		NS		NS		NS		NS	

MF- Magnetic field strength; ED- Exposure duration; Values in parenthesis are percentage decline over the control used for ANOVA analysis and CD value calculation

Table 6: Effect of magnetic fields exposure on sodium concentration (meq L^{-1}) of synthesized salt waters (Mean of the four replication values)

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean
T_1-Control	3.83	13.60	27.18	40.80	56.20	28.32	3.83	13.60	27.18	40.80	56.20	28.32
T_2-0.18T MF + Two minutes ED	3.82	13.59	27.17	40.80	56.19	28.31	3.82	13.59	27.17	40.79	56.19	28.31
	(0.26)	(0.07)	(0.04)	(0.00)	(0.02)	(0.08)	(0.26)	(0.07)	(0.04)	(0.02)	(0.02)	(0.08)
T_3-0.18T MF + Four minutes ED	3.82	13.59	27.17	40.79	56.19	28.31	3.81	13.58	27.16	40.79	56.20	28.31
	(0.26)	(0.07)	(0.04)	(0.02)	(0.02)	(0.08)	(0.52)	(0.15)	(0.07)	(0.02)	(0.00)	(0.15)
T_4-0.18T MF + Six minutes ED	3.81	13.58	27.16	40.79	56.18	28.30	3.81	13.59	27.15	40.79	56.18	28.30
	(0.52)	(0.15)	(0.07)	(0.02)	(0.04)	(0.16)	(0.52)	(0.07)	(0.11)	(0.02)	(0.04)	(0.15)
T_5-0.29T MF + Two minutes ED	3.80	13.59	27.17	40.80	56.19	28.31	3.82	13.58	27.17	40.80	56.18	28.31
	(0.78)	(0.07)	(0.04)	(0.00)	(0.02)	(0.18)	(0.26)	(0.15)	(0.04)	(0.00)	(0.04)	(0.10)
T_6-0.29T MF + Four minutes ED	3.81	13.58	27.16	40.79	56.18	28.30	3.81	13.59	27.16	40.79	56.17	28.30
	(0.52)	(0.15)	(0.07)	(0.02)	(0.04)	(0.16)	(0.52)	(0.07)	(0.07)	(0.02)	(0.05)	(0.15)
T_7-0.29T MF + Six minutes ED	3.81	13.58	27.17	40.79	56.18	28.31	3.81	13.59	27.15	40.79	56.19	28.31
	(0.52)	(0.15)	(0.04)	(0.02)	(0.04)	(0.15)	(0.52)	(0.07)	(0.11)	(0.02)	(0.02)	(0.15)
T_8-0.44T MF + Two minutes ED	3.81	13.58	27.16	40.80	56.18	28.31)	3.81	13.59	27.16	40.80	56.17	28.31
	(0.52)	(0.15)	(0.07)	(0.00)	(0.04)	(0.16)	(0.52)	(0.07)	(0.07)	(0.00)	(0.05)	(0.14)
T_9-0.44T MF + Four minutes ED	3.80	13.57	27.16	40.79	56.17	28.30	3.80	13.58	27.16	40.79	56.17	28.30
	(0.78)	(0.22)	(0.07)	(0.02)	(0.05)	(0.23)	(0.78)	(0.15)	(0.07)	(0.02)	(0.05)	(0.22)
T_{10}-0.44T MF + Six minutes ED	3.80	13.57	27.15	40.79	56.17	28.30	3.79	13.57	27.14	40.78	56.16	28.29
	(0.78)	(0.22)	(0.11)	(0.02)	(0.05)	(0.24)	(1.04)	(0.22)	(0.15)	(0.05)	(0.07)	(0.31)
Mean	3.81	13.58	27.17	40.79	56.18		3.81	13.59	27.16	40.79	56.18	
	(0.55)	(0.14)	(0.06)	(0.02)	(0.03)		(0.55)	(0.11)	(0.08)	(0.02)	(0.04)	
	Saline waters (S)		Treatments (T)		SXT		Saline waters (S)		Treatments (T)		SXT	
SEd	2.3		2.0		1.20		2.42		2.12		1.92	
CD (5 %)	NS		NS		NS		0.41		NS		NS	

MF- Magnetic field strength; ED- Exposure duration; Values in parenthesis are percentage decline over the control used for ANOVA analysis and CD value calculation

Table 7: Effect of magnetic fields exposure on chloride concentration (meq L^{-1}) of synthesized salt waters (Mean of the four replication values)

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean
T_1-Control	2.43	9.70	19.40	29.10	38.80	19.89	2.43	9.70	19.40	29.10	38.80	19.89
T_2-0.18T MF + Two minutes ED	2.42	9.70	19.39	29.09	38.79	19.88	2.42	9.70	19.40	29.09	38.80	19.88
	(0.41)	(0.00)	(0.05)	(0.03)	(0.03)	(0.10)	(0.41)	(0.00)	(0.00	(0.03)	(0.00)	(0.09)
T_3-0.18T MF + Four minutes ED	2.41	9.69	19.38	29.08	38.79	19.87	2.41	9.69	19.40	29.08	38.79	19.87
	(0.82)	(0.10)	(0.10)	(0.07)	(0.03)	(0.22)	(0.82)	(0.10)	(0.00	(0.07)	(0.03)	(0.20)
T_4-0.18T MF + Six minutes ED	2.41	9.68	19.38	29.08	38.78	19.87	2.42	9.69	19.39	29.10	38.78	19.88
	(0.82)	(0.21)	(0.10)	(0.07)	(0.05)	(0.25)	(0.41)	(0.10)	(0.05	(0.00)	(0.05)	(0.12)
T_5-0.29T MF + Two minutes ED	2.42	9.68	19.39	29.09	38.80	19.88	2.41	9.70	19.40	29.09	38.80	19.88
	(0.41)	(0.21)	(0.05)	(0.03)	(0.00)	(0.14)	(0.82)	(0.00)	(0.00	(0.03)	(0.00)	(0.17)
T_6-0.29T MF + Four minutes ED	2.41	9.67	19.38	29.10	38.79	19.87	2.42	9.69	19.39	29.10	38.78	19.88
	(0.82)	(0.31)	(0.10)	(0.00)	(0.03)	(0.25)	(0.41)	(0.10)	(0.05	(0.00)	(0.05)	(0.12)
T_7-0.29T MF + Six minutes ED	2.41	9.66	19.38	29.07	38.79	19.86	2.41	9.68	19.40	29.10	38.78	19.87
	(0.82)	(0.41)	(0.10)	(0.10)	(0.03)	(0.29)	(0.82)	(0.21)	(0.00	(0.00)	(0.05)	(0.22)
T_8-0.44T MF + Two minutes ED	2.42	9.68	19.38	29.09	38.79	19.87	2.41	9.68	19.39	29.09	38.79	19.87

	(0.41)	(0.21)	(0.10)	(0.03)	(0.03)	(0.16)	(0.82)	(0.21)	(0.05	(0.03)	(0.03)	(0.23)
T_9-0.44T MF + Four minutes ED	2.41	9.67	19.37	29.07	38.78	19.86	2.41	9.70	19.38	29.10	38.78	19.87
	(0.82)	(0.31)	(0.15)	(0.10)	(0.05)	(0.29)	(0.82)	(0.00)	(0.10	(0.00)	(0.05)	(0.20)
T_{10}-0.44T MF + Six minutes ED	2.41	9.67	19.37	29.07	38.78	19.86	2.40	9.67	19.37	29.07	38.77	19.86
	(0.82)	(0.31)	(0.15)	(0.10)	(0.05)	(0.29)	(1.23)	(0.31)	(0.15	(0.10)	(0.08)	(0.38)
Mean	2.41	9.68	19.38	29.08	38.79		2.41	9.69	19.39	29.09	38.79	
	(0.69)	(0.23)	(0.10)	(0.06)	(0.03)		(0.73)	(0.11)	(0.05	(0.03)	(0.04)	
	Saline waters (S)		Treatments (T)		SXT		Saline waters (S)		Treatments (T)		SXT	
SEd	0.86		0.62		0.40		0.91		0.63		0.46	
CD (5 %)	NS		NS		NS		NS		NS		NS	

MF- Magnetic field strength; ED- Exposure duration; Values in parenthesis are percentage decline over the control used for ANOVA analysis and CD value calculation

Table 8: Effect of magnetic fields exposure on sulphate concentration (meq L^{-1}) of synthesized salt waters (Mean of the four replication values)

Treatments	Saline waters (dS m^{-1})											
	North pole						South pole					
	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean	S1 (0.5)	S2 (2.00)	S3 (4.00)	S4 (6.00)	S5 (8.00)	Mean
T_1-Control	1.28	5.20	10.40	15.60	20.80	10.66	1.28	5.20	10.40	15.60	20.80	10.66
T_2-0.18T MF + Two minutes ED	1.28	5.20	10.40	15.60	20.79	10.65	1.27	5.20	10.40	15.60	20.80	10.65
	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.01)	(0.78)	(0.00)	(0.00)	(0.00)	(0.00)	(0.16)
T_3-0.18T MF + Four minutes ED	1.27	5.19	10.39	15.59	20.79	10.65	1.26	5.19	10.39	15.59	20.79	10.64
	(0.78)	(0.19)	(0.10)	(0.06)	(0.05)	(0.24)	(1.56)	(0.19)	(0.10)	(0.06)	(0.05)	(0.39)
T_4-0.18T MF + Six minutes ED	1.27	5.19	10.39	15.59	20.78	10.64	1.26	5.19	10.39	15.59	20.79	10.64
	(0.78)	(0.19)	(0.10)	(0.06)	(0.10)	(0.25)	(1.56)	(0.19)	(0.10)	(0.06)	(0.05)	(0.39)
T_5-0.29T MF + Two minutes ED	1.26	5.20	10.39	15.60	20.79	10.65	1.26	5.19	10.39	15.60	20.79	10.65
	(1.56)	(0.00)	(0.10)	(0.00)	(0.05)	(0.34)	(1.56)	(0.19)	(0.10)	(0.00)	(0.05)	(0.38)
T_6-0.29T MF + Four minutes ED	1.27	5.19	10.38	15.59	20.78	10.64	1.26	5.19	10.38	15.59	20.79	10.64
	(0.78)	(0.19)	(0.19)	(0.06)	(0.10)	(0.27)	(1.56)	(0.19)	(0.19)	(0.06)	(0.05)	(0.41)
T_7-0.29T MF + Six minutes ED	1.26	5.19	10.38	15.59	20.78	10.64	1.26	5.18	10.38	15.59	20.78	10.64
	(1.56)	(0.19)	(0.19)	(0.06)	(0.10)	(0.42)	(1.56)	(0.38)	(0.19)	(0.06)	(0.10)	(0.46)
T_8-0.44T MF + Two minutes ED	1.27	5.19	10.39	15.59	20.78	10.64	1.26	5.20	10.39	15.59	20.79	10.65
	(0.78)	(0.19)	(0.10)	(0.06)	(0.10)	(0.25)	(1.56)	(0.00)	(0.10)	(0.06)	(0.05)	(0.35)
T_9-0.44T MF + Four minutes ED	1.26	5.19	10.39	15.58	20.77	10.64	1.26	5.19	10.38	15.58	20.79	10.64
	(1.56)	(0.19)	(0.10)	(0.13)	(0.14)	(0.42)	(1.56)	(0.19)	(0.19)	(0.13)	(0.05)	(0.42)
T_{10}-0.44T MF + Six minutes ED	1.26	5.18	10.38	15.57	20.77	10.63	1.26	5.18	10.37	15.58	20.78	10.63
	(1.56)	(0.00)	(0.00)	(0.00)	(0.00)	(0.50)	(1.80)	(1.56)	(0.38)	(0.19)	(0.19)	(0.83)
Mean	1.27	5.19	10.39	15.59	20.78		1.26	5.19	10.39	15.59	20.79	
	(1.04)	(0.17)	(0.12)	(0.07)	(0.09)		(1.50	(0.19)	(0.14)	(0.06)	(0.05)	
	Saline waters (S)		Treatments (T)		SXT		Saline waters (S)		Treatments (T)		SXT	
SEd	1.2		0.9		0.45		0.95		0.65		0.38	
CD (5 %)	NS		NS		NS		NS		NS		NS	

MF- Magnetic field strength; ED- Exposure duration; Values in parenthesis are percentage decline over the control used for ANOVA analysis and CD value calculation

Conclusion

The electrical conductivity of saline water gets declined for exposure of magnetic field which was highly depends on salt content of the water, exposure durations and magnetic orientations. The magnetic effect decreased with increase of salt content, which were more effective up to saline waters EC 2.18 dS m-1. The magnetic effect was relatively more under the south magnetic orientations. The increase of magnetic strength and exposure durations decreased the EC value of saline waters. Overall, 0.44T magnetic field strength and exposure duration of six minutes can be recommended for treating poor quality saline waters before irrigation to crops. Since, the magnetic field did not affect the chemical composition of saline waters it might be more related to structure of ion orientation get altered by the magnetic field. Thus, it is advocated the future research on ions orientation and structure change for saline waters exposure to range of magnetic fields for elucidating real cause of EC value declines. From agriculture point of view, it is also necessary to study magnetized water reaction with different soils and crop performance in order to achieve a high and sustainable crop yield.

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