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# EFFECTS OF MAGNETIC SALINE WATER APPLICATION FOR IMPROVING PHYSIOLOGICAL PARAMETERS OF TOMATO (*Solanum lycopersicum*) SEEDLINGS

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**Abstract**

*Among the main environmental problems in arid and semi arid regions is the shortage of freshwater. To overcome this problem, lower quality-water, such as saline groundwater, is widely used. The use of saline water after magnetization could be a solution of the problem of water scarcity. This study examines the effects of water magnetic treatment on physiological responses of tomato seedlings. These plants were subjected to two kind of irrigation: potable water (EC: 2.5 mS/cm) and saline water from groundwater (EC: 7.5 mS/cm). The results collected during this study suggest that the effects of magnetic treatment varied with the type of irrigation water used. In particular, the magnetic treatment of saline water increased tomato dry weight significantly as compared to potable water. Irrigation with magnetic saline water indicate some beneficial effect on the seed germination, photosynthetic pigments, photosynthesis and stomatal conductance of tomato seedlings under controlled environmental conditions. The malondialdehyde content in leaves decreased when the tomato seedlings was irrigated with potable water, magnetic potable water and magnetic saline water, but increased with non magnetized saline water. The malondialdehyde content and activities of superoxide dismutase (SOD) and glutathione peroxidase (GPx) in leaves increased significantly with irrigation by non magnetized saline water. The positive effects were more pronounced for magnetic treatment of saline water. This study suggests that the effects of magnetic treatments act as a protective factors against water salinity.*

**Key Words:** *Water magnetic treatment, Seedlings growth, Antioxidant enzymes, Physiological responses*

## Introduction

In arid and semi-arid regions water is a primary resource limitation to plant growth (McLendon *et al*., 2008). These environments are exposed to extreme deficits of water during the largest part of the year due to low rainfall and relatively high evapotranspiration rates. Therefore, agriculture in these regions relies on irrigation. Among the main environmental problems in these regions is the shortage of freshwater. To raise this problem, lower quality-water, such as saline groundwater, is widely used (Feikema *et al*., 2010; Verma *et al*., 2012). Groundwater salinity generally exceeded 3 g/l. Salinity stress was the most serious abiotic stress factors causing environmental problems and limiting growth. Salt stress affects plant physiology, both at whole plant as well as cellular levels, through osmotic and ionic stress. It affects plant water relations negatively, which results a physiological drought or osmotic stress (Munns, 2002; Rady, 2011). The major physiological characteristics, such as photosynthesis, proteins, lipids and chlorophyll were affected under salt stress (Rady, 2011; Kahrizi *et al*., 2012).

In recent years, to resolve the problems of water scarcity and its salinity much research carried out on effect of magnetic field in water treatment to enhancement its productivity Maheschwari, 2009; Aladjajian, 2010). It is advanced that the main magnetic effects concern the association of ions which are involved in the nucleation process of calcium carbonate precipitation. Therefore, magnetic treatment (MT) affects dispersion solubility, crystallization, hydration of ions and hydrodynamics of fluid flow (Alimi *et al*., 2006). Alimi *et al*. (2009) showed that MT affect calcium carbonate crystallization by increasing the total precipitate quantity and by favoring its formation in the bulk solution instead of its incrustation on the walls. Colic and Morse (1999) indicates that magnetic field and/or electromagnetic field can produce small amounts of free radicals and hydrogen peroxide and it is well known to biologists that these small amounts of hydrogen peroxide enhance plant growth.

In general, the literature reveals that there are some beneficial effects of magnetic field or treatment on plant growth and other physiological parameters. For example, Maheshwari and Grewal (2009) showed an increase in water productivity in crop production with magnetically treated water. Noran *et al*. (1996) reported differences in the concentrations of K, N, P, Ca, Mg and Na in soils irrigated with magnetically treated water when compared those with normal water. Maheshwari and Grewal (2009) showed a decrease in soil pH after magnetically treated water treatment. Organic acids released in rhizosphere may be responsible for desorption of P and K, and thus making these nutrients more available to plants. Podleoeny *et al*. (2004) studied the effects of magnetic treatment by exposing the broad bean seeds to variable magnetic strengths before sowing and observed marked beneficial effects on seed germination. Reina *et al*. (2001) found significance increase in the rate of water absorption accompanied with an increase in total mass of lettuce with the increase of magnetic force. Magnetic fields can influence the root growth of some plant species (Turker *et al*., 2007; Grewal and Maheshwar, 2011). Turker *et al*. (2007) reported a beneficial effect of magnetic field on root dry weight of sunflower plants, but there was an inhibitory effect of magnetic field on root dry weight of maize plants.

Therefore, the aim of this study was to investigate the effects of magnetically treated irrigation water (saline water and tap water) on some physiological traits of tomato (*Solanum lycopersicum*) seedlings grown under controlled conditions.

## Materials and Methods

***Experimental Conditions:*** The experiments performed in a glasshouse located at Engineering school. The composition of potable water and saline water from groundwater is presented in table 1. The respective electrical conductivity (EC) is 2.5 and 7.5 mS/cm. The soil was dominated by sand (65 %) and silt (28.6%), with smaller proportions of clay (6.4%). Tomato seeds (*Solanum lycopersicum* L. cv. Chebli) were germinated on wet filter paper in darkness at 25 ±2 °C for 7 days. Following germination, seedlings of approximately equal size were transferred into 3-L pots. The pots for each kind of water were irrigated twice on a week.

Table 1: Effects of magnetic treatment on mean values of pH, EC, salinity, macro and micronutrients concentrations in different types of irrigation waters.

| | Potable water | | saline water | |
|---|---|---|---|---|
| | Control | magnetic water | Control | magnetic water |
| pH | 7.97±0.1 | 8±0.15 | 7.75±0.02 | 7.91±0.04 |
| EC (ms/cm) | 2.5±0.3 | 2.5±0.1 | 7.5±0.15 | 7.4±0.1 |
| Salinity (g/l) | 1.85±0.2 | 1.85±0.1 | 5.62±0.15 | 5.6±0.1 |
| $Ca^{2+}$ | 184±3 | 188±7 | 805±6 | 800±8 |
| $Mg^{2+}$ | 77± 2 | 73±5 | 205±3 | 201±2 |
| $Na^{+}$ | 381±6 | 390±8 | 830±6 | 840±2 |
| K+ | 13±0.8 | 13.3±1 | 17±1 | 17±2 |
| $HCO_3^-$ | 228±6 | 228±8 | 128±5 | 108±3 |
| $Cl^-$ | 670±8 | 660±14 | 1400±13 | 1400±20 |
| $SO_4^{2-}$ | 440±10 | 430±15 | 2250±20 | 2280±10 |

The different type waters were treated with a magnetic device before applying to the plants. Magnetic treatment device, supplied by SOFILTRA, with its magnetic field of 0.85 T was used for the magnetic treatment of irrigation water.

For growth measurement, at the end of the experiment the plant samples were washed with distilled water to remove the mechanically adhering impurities, dried with filter paper and immediately used for biomass determination. Leaves, stems and roots were separated. Plant tissues were oven-dried at 60 °C until reaching a constant weight, and dry weights were recorded. The plant tissues were ground for chemical analysis. All analyses were done in triplicate.

***Water Analysis:*** The chemical parameters of the studied water samples were determined by standard methods. The pH of water samples was determined using a pH meter (Model EA940, Orion, USA) and the conductivity was measured by a conductivity meter (Model WTW LF 90). Total nitrogen was determined by Kjeldahl (1883) method. K, Na, Ca and Mg were determined by atomic absorption spectrophotometry (Thermo Scientific EC 3200).

***Germination Bioassay:*** Ten seeds from tomato (*Solanum lycopersicum*) were placed on filter papers in glass Petri dishes with dimensions 110 mm x 20 mm. 10 ml of each water samples were then uniformly added to each dish. The dish was capped and kept in a dark incubator at 25°C temperature for 5 days. 10 ml of distilled water were used for the controls, instead of saline or tap water. A germination index (GI) was calculated by accounting the number of grown seeds and the average sum of seeds' root elongation in a sample as related to the control (Zucconi *et al*., 1981). Results were finally expressed as a percentage.

***Leaf Gas Exchange Measurements:*** After 60 days of growth, the measurements of photosynthetic activity (Pn) were carried out on leaves selected from the median part of the shoots (Elloumi *et al*., 2014a, b). Pn was measured on well-exposed three leaves per plant from four plants per treatment from 10:00 to 11:00 pm using a portable gas exchange system (Li-Cor Inc.6200). Stomatal conductance rate was evaluated by a portable porometer (Steady State Porometer model MK III, DELTA –T DEVICES).

***Chlorophyll and Carotenoids Concentrations:*** Chlorophylls a and b and total carotenoids were extracted in 80% acetone. The concentration of each pigment (as µg/ml) was calculated according to the formulae of Lichtenthaler (1987).

***Enzyme Determinations and Lipid Peroxidation:*** At the end of the experiment, plants used for enzyme determinations were removed carefully from the soil in the early morning. Soluble protein and antioxidant enzyme activities of roots and leaves were determined spectrophotometrically. Using a pre-cooled mortar and pestle, 0.5 g of leaf or root tissues were homogenized in 0.8 ml of 100 mM ice-cold potassium phosphate buffer (pH 7.0) containing 0.1 mM ethylene diamine tetraacetic acid (EDTA), 1 mM phenyl methyl sulfonyl fluoride (*PMSF)* and 3.75% polyvinylpyrrolidone (PVP). The homogenates were centrifuged at 15,000 g for 15 min and the supernatants used for the determination of soluble protein and enzyme activities. All procedures were performed at 0–4°C. The content of soluble protein was estimated from leaf and root samples using the method of Lowry *et al.* (1951). SOD (EC: 1.15.1.1) activity was determined with the method of Giannopolitis and Ries (1977) following the inhibition of photochemical reduction due to nitro-blue tetrazolium (NBT). Activity of GPx (EC: 1.11.1.9) was determined using the method of Flohe and Gunzler (1984) by monitoring the decrease in absorbance at 340 nm for 1 min.

Lipid peroxidation was estimated by measuring the level of thiobarbituric acid reactive substances (TBARS) in plant tissue extracts (Esterbauer, 1993).

***Statistical Analysis:*** All statistical analyses were performed using analysis with SPSS version 17 software. Duncan multiple range test was performed to test the significance of difference between the treatments.

## Results and Discussion

### *Water Properties*

The mean values of pH, EC, Ca, Mg, Na, K, Cl, $HCO_3^-$ and $SO_4^{2-}$ of different irrigation water types before and after magnetic treatment are presented in Table 1. The variation of pH did not exceed

0.15 units for saline water, while there is no apparent trend for pH values over potable water with magnetic treatment. As far as the soil electrical conductivity, no significant difference was noted between the magnetic treatment and the control over the two water kinds. The values of Ca, Mg, Na, Cl, Na, K, $HCO_3^-$ and $SO_4^{2-}$ contents of different water types were not affected by magnetic treatment of water. Saline water had greater Ca, Mg, Na, K, $HCO_3^-$ and $SO_4^{2-}$ content compared with tap water (Table 1). Our results are consistent with those of Maheshwari and Grewal (2009) who reported that the values of N, P and K contents of different water types (recycled water, tap water and saline water) were not affected by magnetic treatment of water. Similarly, Alimi *et al.* (2009) have signaled that the magnetic treatment did not induce any significant $CO_2$ departure due to water agitation, and that no $CaCO_3$ particles could be formed during the treatment time.

***Germination Bioassay***

After the water magnetic treatment, the tomato germination index showed values above 105% in all the treated water when compared to the control water (Figure 1). However, the results with the untreated saline and potable water presented a decrease in germination index of 23% and 45% when compared to the control (distilled water). Regarding sensitivity to the salt, *Solanum lycopersicum* showing a great reduction in germination (GI= 55%). In spite of this decrease, the GI values remained between 50–80% indicates moderate toxicity. According to Zucconi *et al*. (1985), GI≥80% indicates no presence of phytotoxic substances; GI between 50–80% indicates moderate toxicity, GI≤50% indicates high toxicity and values greater than 100% shows a beneficial effect on seed growth (Komilis and Tziouvaras, 2009). Our results demonstrate clearly the beneficial effect of magnetic treatment on seed germination of *Solanum lycopersicum* (GI>100%). Selim (2008) reported that the effect of magnetic treatments of seeds and irrigation water on seedling of some filed crops such as wheat and barley grown in saline sandy soil has come to be the most effective treatment in seed germination as compared with control. Guo *et al*. (1994), reported that magnetizing seeds is very efficient to increase the number of germinating seeds and to hasten the germination process.

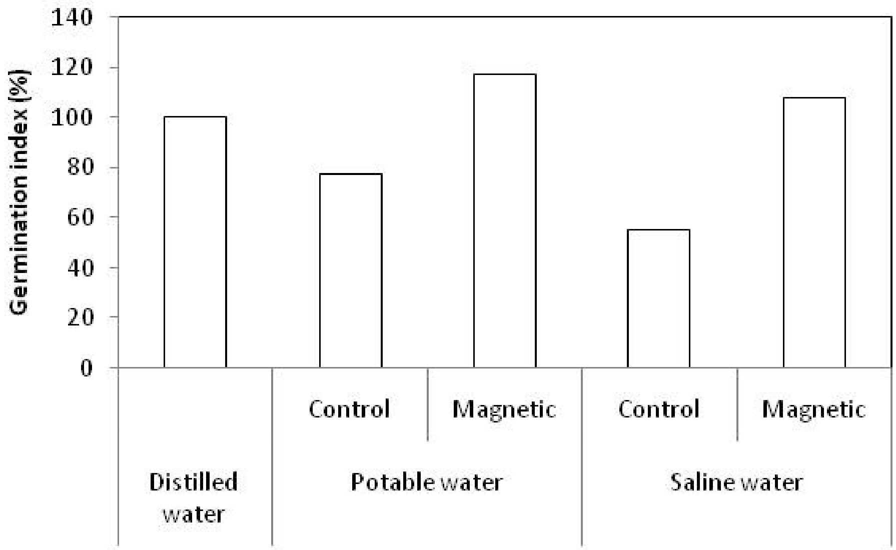


Fig. 1: Germination index (GI) obtained for *Solanum lycopersicum* seeds

***Effects on Growth***

As seen in Table 2, after 60 days of irrigation with saline magnetic water, the dry weight of the leaves, stems and roots of the tomato seedlings increased as compared to seedlings irrigated with non magnetized water. The improvement for magnetic saline water over control treatment reached to 137% for leaves dry weight (mg/plant), 29% for stems dry weight (mg/plant) and only 3% for roots dry weight (mg/plant), while for potable water no significant difference was noted for control and magnetic water. These results are in conformity with those obtained by De Souza *et al*. (2006) on tomatoes, who found a significant increase in dry weights of root, shoot and whole plants as a result of treating plant with magnetic technologies. Selim and Nady (2011) reported that there was significant increases in plant height, root length, number of leaves, leaf area, fresh and dry weights of different organs, specific leaf area, leaf area ratio, leaf weight ratio and leaf area index of tomato plants as a result of the application of magnetic technologies. Abdul Qados and Hozayn (2010) reported that the simulative effect of magnetized water on growth parameters may be attributed to the induction of cell metabolism and mitosis. Several research noted the simulative effect of magnetized water on growth parameters of different plant species (Yaycih and Alikamanoglu, 2005; Celik *et al*., 2008; Nasher, 2008).

Table 2: Effects of magnetic treatment of irrigation water types on mean values of leaves, stems and roots dry weight of tomato seedlings.

| | Leaf dry weight | Stem dry weight | Root dry weight |
|---|---|---|---|
| Water source | | | |
| Control | | | |
| *Potable water* | 555.7±13.3a | 345.3±8.1a | 148.7±35.2a |
| *Saline water* | 126±5.2c | 200.6±4c | 70.3±5.7b |
| Magnetic water | | | |
| *Potable water* | 540±9.2a | 326.7±23.8a | 147.7±10.9a |
| *Saline water* | 299.3±3.1b | 258.7±42.1b | 72±1.7b |

Means with different letters indicate a significant difference at $P \leq 0.05$ using Duncan multiple range test

***Photosynthesis and Chlorophyll Contents***

The response of photosynthesis and stomatal conductance to magnetic water treatment is shown in Figure 2. There was a tendency for higher photosynthetic rates in the tomato seedlings irrigated with potable water compared to these irrigated with saline water. Net photosynthetic rate (*Pn)* showed an increasing trend with magnetic water treatment. While the level of *Pn* with magnetic saline water treatment increased by 80% compared with control. However, with magnetic potable water, it exhibited an increase only by 30%. Similar trends were observed for *Gs* with the magnetic treatment for the two water kinds. *Gs* values were all substantially increased compared to the control values. There were several possible explanations for the close relationship between *Pn* and *Gs* under the water magnetic treatment. For example, the variation in *Pn* may be largely a result of variations in *Gs*, caused by adjustments in stomatal aperture (Chen *et al.*, 2010). The *Pn* is determined by stomata closure, which is controlled by turgor pressure of the leaf cells.

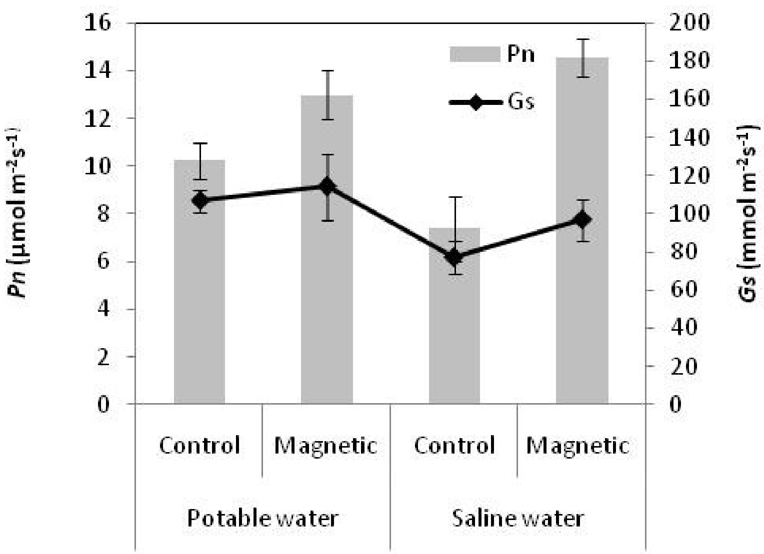


Fig. 2: Net photosynthetic rate (Pn, µmol $CO_2$ $m^{-2}$ $s^{-1}$) and stomatal conductance (Gs, mmol $m^{-2}$ $s^{-1}$) of tomato seedlings irrigated with magnetic water

The photosynthesis pigments expressed as chlorophyll a, chlorophyll b, total chlorophyll and carotenoids value in tomato leaves is illustrated in Table 3. After the irrigation with saline water chlorophyll a, chlorophyll b, total chlorophyll and carotenoids values decreased as compared with those irrigated with tap water. Our results show also that magnetic treatment increased significantly the contents of chl a, b and total chlorophyll in leaves of tomato seedlings irrigated with saline and potable water as compared to the plants irrigated with non magnetic water. The stimulating effect of magnetic treatments on photosynthesis pigments may be due to increasing stomatal conductance, which leads to increase photosynthetic efficiency. Selim and El-Nady (2011) reported that the stimulating effect of magnetic treatments on photosynthetic pigments may be due to increasing proline content. This rise in proline content increased the number of some ions such as Mg2+ needed for chlorophyll synthesis and/or K+ (Garcia-Reina and ArzaPascual, 2001).

Table 3: Effects of magnetic water treatment on chlorophyll a (*Ca*), chlorophyll b (*Cb*), the ratio of *Ca/Cb*, total chlorophyll (Ca+b), carotenoid (Cx+c) and the ratio of Ca+b/Cx+c in *Solanum lycopersicum*.

| | Potable water | | Saline water | |
|---|---|---|---|---|
| | Control | magnetic water | Control | magnetic water |
| *Ca* | 11.9±0.48c | 13.8±0.01d | 7.4±0.16a | 8.7±0.02b |
| *Cb* | 6.08±0.95c | 12.20±0.07d | 5.01±0.15a | 5.26±0.21b |
| *Ca+b* | 17.98±1.3c | 25.97±0.08d | 12.53±1.20a | 14.01±0.20b |
| *Cx+c* | 2.40±0.48c | 1.98±0.79b | 1.69±0.07a | 1.48±0.33a |
| *Ca/Cb* | 1.95 | 1.13 | 1.46 | 1.66 |
| Ca+b/ Cx+c | 7.47 | 13.07 | 7.39 | 9.44 |

Means with different letters indicate a significant difference at P ≤ 0.05 using Duncan multiple range test

Our results showed a decrease in carotenoid content in different water magnetic treatment. Carotenoids, non-enzymatic antioxidant, play a significant role in the protection of chlorophyll pigment under stress conditions by quenching the photodynamic reactions, replacing peroxidation and collapsing of membrane in chloroplasts (Kenneth et al., 2000).

***Leaves Damage Endpoint Responses***

Irrigation of tomato seedlings with saline water induced lipid peroxidation in leaves (Figure 3). The level of lipid peroxides, expressed as thiobarbituric acid reactive substances (TBARS). TBARS is the product of membrane lipid peroxidation, and its content reflects the degree of cell membrane damage when exposed to reactive oxygen species (ROS). In the present study, the TBARS formation significantly increased in leaves of tomato seedlings irrigated with saline water (Figure 3). Several researchs reported an increase in TBARS under salt stress (Sairam et al., 2002; Yildiztugay et al., 2014). After the magnetic treatment of saline water, the leaves TBARS contents decreased to 1.1nmol mg-1 protein. TBARS content in leaves decreased remarkably due to the magnetic treatment of saline water. In leaves irrigated with saline water, magnetic treatment decreased TBARS acuumulation, which indicated that oxidative stress by magnetic treatment can be prevented by decreasing saline stress. The increase of TBARS formation is a direct consequence of increased ROS formation and thus of unsaturated fatty acid peroxidation.

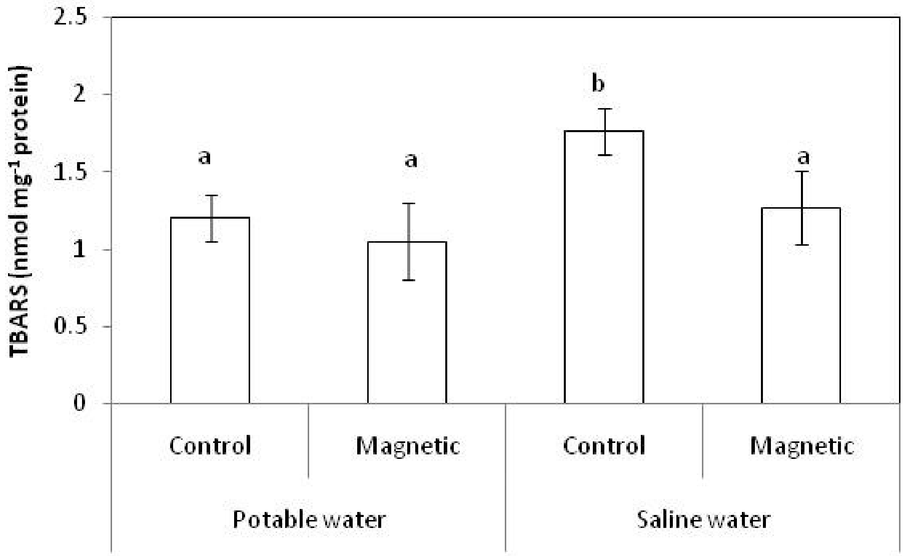


Fig. 3: Effect of magnetic treatments on lipid peroxidation (TBARS) in tomato seedlings. Means with different letters indicate a significant difference at P ≤ 0.05 using Duncan multiple range test.

Altered activities of antioxidant enzymes and antioxidants have been commonly reported and are frequently used as indicators of oxidative stress in plants (Mittler, 2002). Of the common antioxidant enzymes, Superoxide dismutase (SOD) is considered as the vital first-line defenses against oxygen toxicity (Üner *et al*., 2005). For all enzymes tested in this experiment, SOD and glutathione peroxidase (GPx) activities increased significantly in tomato seedlings irrigated with saline water compared to plants irrigated with potable water. In leaves of saline water treatment, the SOD activity was 1.28 fold higher than those of potable water treated plants (Figure 4). For the GPx activity, this increase was 1.33 times. Results show that leaves of tomato seedlings treated with magnetic saline water presented significantly lower activities of SOD and GPx than tomato seedlings treated with non treated saline water. The activities of SOD and GPx in leaves of tomato seedlings irrigated with magnetic saline water were similar to that magnetized tap water and non magnetized. The beneficial effect of magnetic treatment was more significant for saline water than with tap water.

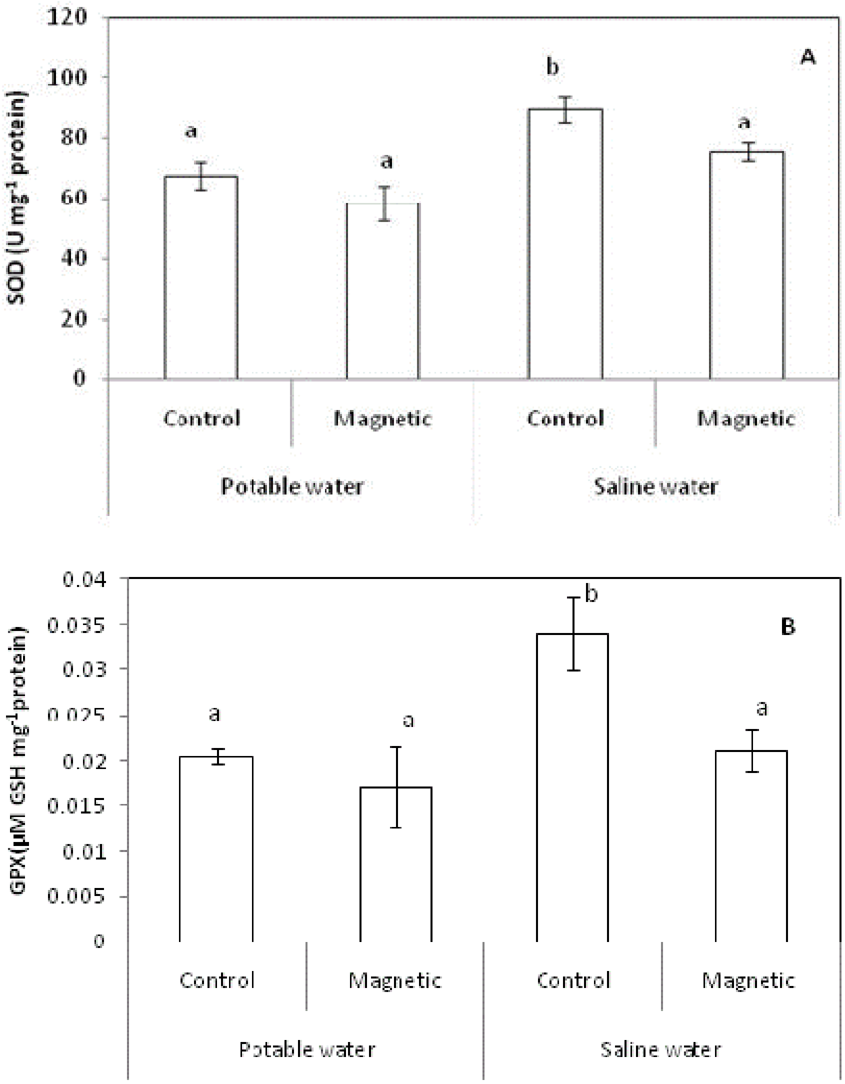


Figure 4. Effect of magnetic treatments on the activities of Superoxide dismutase (SOD) (A) and Guaiacol peroxidase (GPX) (B) in tomato seedlings
Means with different letters indicate a significant difference at $P \leq 0.05$ using Duncan multiple range test

## Conclusion

The current study demonstrates some beneficial effects of magnetically treated water and plays an important role in the protection of tomato seedlings against the adverse effects of salt stress. The beneficial effect of magnetic treatment was more significant for saline water than with tap water. Besides, magnetic treatment play a critical role in tomato seedlings irrigated with saline water by protecting photosynthetic activity and elevating oxidative stress that derived from salt stress.

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