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Effects of Different Magnetically Treated Waters on Emergence and Growth of Snail Medic

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Abstract: The present study concerns the effects of different magnetically treated waters, using distilled water as control, domestic water, saline water (-3 MPa), wastewater and purified water of Arak city; on emergence and growth of Medicago scutellata (Var. Rabinson) seedlings in greenhouse conditions. The various waters were treated by a magnetic field of 250 mT at flow rate of 2 l/min. One hundred seeds per treatment were soaked in magnetically treated waters for 12 hours and cultivated in pots with sand bed. A daily number of emerged seedlings was counted in a daily basis, whereas growth data was measured on the 20th day after planting. Seedlings from seeds exposed to magnetically treated waters showed an improvement of 5-10 percent in the emergence and a 5-14 and 2-16 percent increase in root length and weight, respectively. The values of seedling lengths and dry weight of emerged seedlings in magnetically treated pots, compared with those in untreated pots, showed an increased for distilled water (14.82 and 14.4%), domestic water (14.67 and 16.3%), saline water (13.75 and 9.18%), and purified water (14.04 and 2.92%), respectively. From a practical point of view, it was found that the use of this method is appropriate for improving the agricultural products.

Keywords: Emergence index, Greenhouse, Magnetic field, Sand culture.

Introduction

Iran is in arid and semiarid regions of the world with mean annual precipitation of 393 mm and mean, minimum, and maximum temperatures of 18.3, 11.5 and 25.1°C, respectively, being the climatic condition of this country is very critical for crop production. Under dry land conditions of semi-arid regions, many environmental factors affect germination and subsequent emergence, but availability of moisture is a major problem (Sharafi and Ghaleni, 2022). Thus, the need for new crop variety has strongly increased due to increasing drought problems. Snail medics plays an important role in animal feeding due to their preference value for animals, their high minerals, and their different vitamins. Additionally, it could have positive effects on soil of rangelands through preserving them from erosion and increasing soil nitrogen. Therefore, snail medics can be planted in pastures and dry lands (Sharafi et al. 2006).

Various methods of physical influence on seed germination and seedling emergence have been intensively investigated because seedling establishment is the most sensitive period of crop growth stage (Vashisth and Nagarajan 2010; Shine et al. 2011; Shine and Guruprasad 2012; Sharififar et al. 2015). Poor germination and decreased seedling growth resulted in poor establishment and occasionally crop failure (Gholami et al. 2010). The mechanism of seed germination by magnetic field may be due to changes in physiological and biochemical processes and acceleration of metabolism and activity of those enzymes that accelerate germination (Podlesny et al., 2003; Shahin et al. 2016; Hachicha et al. 2018). Asadi-Samani et al. (2013) reported that the enzymes involved in the germination process (alpha-amylase, protease and dehydrogenase) in seeds treated with magnetic field are due to the effect of ionic currents in the embryonic cell membrane that changes in osmotic pressure and ionic concentrations in induces both sides of the membrane. A change in ionic current across the cell membrane leads to a change in the mechanism of water uptake, because osmotic regulation in embryonic cells is controlled by ion induction across the membrane (Bilalis et al., 2013; Izmailov et al. 2018).

Magnetically treated water affected the growth of the plants, especially in greenhouse and smallholder conditions (Racuciu and Creanga 2005). Several researchers found that magnetic treatments of 125 mT and 250 mT have some impacts on the initial stages of plant growth and increase the germination rate of some seeds such as rice (Florez et al. 2007), pea (Carbonell et al. 2011), lentil (Martínez et al. 2009; Gholami et al. 2010), tomato (De Souza et al. 2005), and snail medic (Gholami et al. 2010; Sharafi 2020). Sharafi (2020) concluded that the magnetic treatment of 250 mT had more positive effect than 125 mT field on snail medic seedlings.

As a pioneer research, El-Zawily et al. (2019) using fresh and agricultural drainage water with or without applying of magnetic field on the tomato growth. They revealed that growth parameters, early, total and relative yield, marketable yield and total chlorophyll and NPK content of leaves were gradually decreased with increasing the irrigation using agricultural drainage water. However, irrigating tomato by 100% fresh water had the highest values, while using of 100% agricultural drainage water displayed the lowest values. Also, Xu et al. (2017) and Hachicha et al. (2018) studied the role of magnetic treatment of saline water on seed germination of potato and corn crop. Their results showed that seedling germination rate is considerably increased with the use of magnetic-treated saline water (EC = 4 ds m^{-1}). The investigations of Grewal and Maheshwari (2011) on chickpea, celery, and snow pea and Hozayn and Qados (2010) on wheat showed that magnetically treated water improved the quantity and quality of mentioned crops in greenhouse conditions.

According to review of the literature, there are few studies, particularly looking into the impacts of different magnetically treated waters on agricultural improvements. These studies have shown that magnetically treated water could be used as an appropriate method to enhance the yield of agricultural products. Furthermore, there is a gap in knowledge about the impact of treated waters by magnetic field on the growth of *Medicago scutellata* (Var. Rabinson). It seems that magnetically treated water can improve seedling growth of snail medic, however, extensive studies are needed on different waters treated by magnetic field. Thus, the main objective of the present research was to evaluate the role of various types of waters treated by magnetic field (250 mT) on seedling growth of snail medic seeds under controlled conditions.

Materials and Methods

Magnetically treated waters

The experiments were performed at Greenhouse Research Center of Department of Agriculture and Environment of Arak University (Arak, Iran). Germination tests were carried out according to the guidelines issued by the International Seed Testing

Association in laboratory conditions (AOSA, 1983). In this experiment, the role of various magnetically treated waters, including distilled water (control), domestic water, saline water (-3 MPa), wastewater and purified water of Arak city; on the emergence attributes of *Medicago scutellata* Var. Rabinson was studied in four replications. Water from various sources were treated magnetically by a magnetic field of 250 mT at flow rate of 2 l min^{-1} (Fig. 1). According to Sharafi (2020), the highest germination percentage for snail medic occurred at the salinity of -3 MPa and in the magnetic field of 250 mT. Therefore, these conditions were considered for the preparation of magnetic water. The experiment was conducted as completely randomized design (CRD) with four replications.

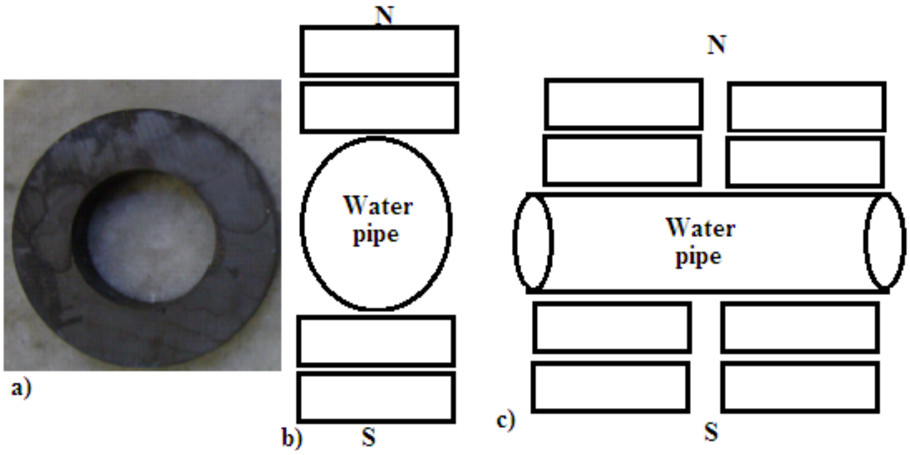

Figure 1 - a) Magnet; b) front view of pipeline containing water; and c) lateral view of vessel containing water.

Water Analysis

Before performing the experiments, the water samples were evaluated for pH, electrical conductivity (EC), and total dissolved solids (TDS). After exposure to the magnetic field, all samples were transferred to the laboratory for re-analysis. Table 1 presents these results. The values of EC and TDS showed a significant decrease under the magnetic field effects. This decrease in the distilled water was also quite evident. Although the pH values showed a relative increase. This is directly related to a reduction in salinity along with increasing the pH value (Table 1).

Table 1 - Values of EC, pH, and TDS before and after magnetically treatment

Water source	Before magnetically treatment			After magnetically treatment		
	EC (ds m^{-1})	pH	TDS (mg l^{-1})	EC (ds m^{-1})	pH	TDS (mg l^{-1})
Distilled	0.62	8.41	5.9	0.34	8.45	4.22
Domestic	0.375	7.73	376	0.253	7.91	257
Saline	6.74	7.62	6720	5.81	7.88	5921
Wastewater	1.23	5.7	683	1.01	6.6	632
Purified	1.23	7.6	690	1.02	7.81	668

Experiment setup

To determine the moisture content of seeds, 20 seeds were weighed in four replications (W_1), they were then dried and re-weighed at 104 °C for 24 h (W_2), as presented at Equation 1:

$$Seed\ moisture\ content = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

The initial dry weight of snail medics seeds was 22±0.3 mg. The soil used in this experiment was sandy texture (containing 5% clay, 4% silt and 91% sand, 23% lime stone and less than 0.3% organic matter). 25 seeds per pots were used for each treatment. Seeds were soaked in water for 12 hours and cultivated in the uniform pots with sand bed. The artificial light cycle was 12 hours light per 12 hours of darkness, with a daily temperature of 20 ±1 °C and a night temperature of 18 ± 1 °C.

The number of emerged seeds were recorded two times per day for the time necessary to achieve the final number or percentage of emerged seeds (E_{max}). Seeds were observed daily for up to 20 days and considered emerged when the shoot was approximately 2 mm long or more. Another important parameter of seed emergence is mean emergence time (MET), that represents the time required for emergence. The rate of emergence was assessed by determining the mean emergence time and the time needed for 50 percent emergence of seeds (TE_{50}). The estimation of time taken for cumulative emergence to 50 percent of maximum at each treatment was interpolated from the emergence progress curve against the time. The emergence rate (TER_{50}, d^{-1}) was calculated using Equations 2 and 3:

$$MET = \frac{\sum Dn}{\sum n} \quad (2)$$

$$TER_{50} = \frac{1}{TE_{50}} \quad (3)$$

where, D is the days from the beginning of emergence and n is the seed numbers emerged on day Di^{th}.

Also, the length (LES) and weight of emerged seedling (WES), seed emergence percentage (SEP), emergence index (EI), and emergence rate index (ERI) were evaluated. Final emergence percentage was calculated after 20 days at the end of experiment by using simple percent formula (Eqs. 4 to 6).

$$SEP = \frac{Seedling\ emerged\ after\ 20\ days}{Total\ of\ number\ of\ seeds\ planted} \times 100 \quad (4)$$

Emergence index was determined according to the method developed by Association of Official Seed Analysis - AOSA (1983):

$$ERI = \frac{Emerged\ seed}{first\ day} + \frac{Emerged\ seed}{second\ day} + ... + \frac{Emerged\ seed}{ni\ day} \quad (5)$$

Emerged seeds were considered daily and applied for determining the emergence rate index (ERI).

$$ERI = \sum_f^l \frac{[\%n - \%(n-1)]}{n} \quad (6)$$

where, %n is the percentage of seedlings emerged on day n, %(n-1) is the percentage of seedlings emerged on day n-1, n is the number of days after planting, f is the first day, and l is the last day of the test.

Statistical analysis

To statistically analyze the results, the data normalization test was performed using Kolmogorov-Smirnov, Anderson-Darling and Chi-square tests (at the levels of 1 and 5%). The results of data normalization values showed that none of the studied treatments in these experiments were significant at the levels of 1 and 5 percent. Then, the data from each treatment were separately analyzed using the Statistical Analysis System (SAS) version 18 software, only comparing the effect of the water magnetic treatment for each water type and dependent variable. Mean comparisons were performed by least significant difference (LSD) test at the level of 5 percent (Rodriguez, 2011). Correlation analysis was performed using Pearson correlation coefficient between the studied traits.

Results and Discussion

Emergence percentage

The stages of emergence and establishment of seedling are important for analyzing early seed growth under controlled conditions as it can predict the crop yield. Figure 2 shows the emergence percentage of snail medic seed in different magnetically treated waters. Based on the results, seed emergence started three days earlier in wastewater treatment, two days earlier in saline water treatment, and one day earlier in distilled water treatment with the application of magnetic-treatment, in comparison with non-treated water (control treatment).

A positive relationship was observed between seedling emergence and the end of germination stage in waters treated with magnetic field including distilled water, domestic water, and purified water. In other words, the percentage of seedling emergence values was higher in pots magnetic treated water and had a relatively constant trend (Fig. 1).

Poor seedling establishment in turn causes subsequently high loss of water through osmotic pressure and lower availability of water for crop and lower growth in early stages when vapor pressure deficit is low, therefore, CO_2 exaction per unit transpiration loss is diminished (Gholami et al., 2010). Magnetic field induced changes in mild salinity concentration (-3 MPa) and osmotic pressure, regulating the water entrance into the seeds (Podleoeny et al., 2004; Florez et al., 2007; Sharafi et al., 2019).

Growth traits

Figure 3 shows the average of seedling weight, time to reach 50 percent of seed emergence, seedling length, and seed emergence rate of snail medic measured after 20 days. As can be seen, with the use of magnetically treated water, the length and weight of snail medic seedling are more than that of for the control treatment. It can be observed that the seedling weight increase by 14.48, 13.65, 16.3, 9.18, and 2.9 percent in distilled water (as control treatment), domestic water, saline water, wastewater, and purified water, respectively. These increases were reported 7.04, 18.5, 24.6, 2.7, and 20.4 percent for the length of emergence seeds, respectively.

The maximum increase in the seedling lengths was observed with using the magnetic purified water, whereas the emerged seed weights had an inverse relationship with magnetically treated saline water (Fig 1 a-c). Increasing the seedling length and weight may be attributed to earlier emergence of snail medic seedling irrigated with magnetically-treated water on the contrary of their control treatment; Therefore, the seed captured more days (2 to 3 days) to grow than the control treatment.

According to the results, the time taken to the reach 50 percent of emergence in saline water and wastewater treatments (in both control treatment and the application of magnetically-treated water) occurred after 14.91, 15.3, and 14.72 days, respectively, whereas, in control treatment with distilled water, 50 percent of emergence happened after 9.5 days. Because of the positive relationship between the decrease in the time taken to reach 50 percent of emergence and the growth rate of the seedlings, there is no significant difference in the growth rate through treatment with magnetically treated water for purified water and domestic water as compared with the control treatment (non-treated distilled water).

The highest growth rate was observed in control treatment with distilled water (0.105 mg d-1), the application of magnetically treated water for domestic water (0.101 mg d-1), and purified water from wastewater (0.1 mg d^{-1}), respectively. Whereas the treatment with saline water and wastewater showed the lowest seedling growth rate (Fig. 3b-d).

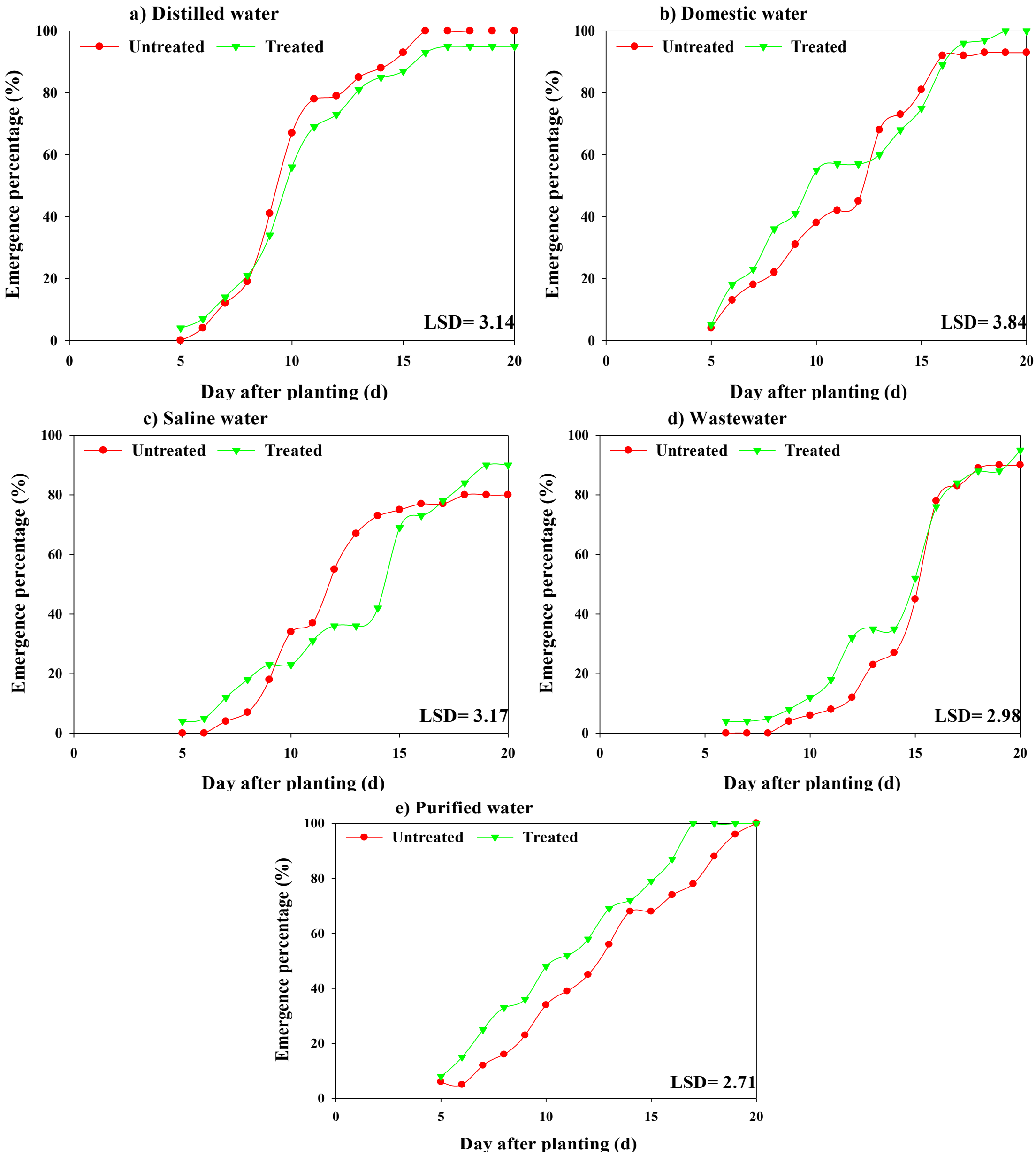

Figure 2 - Seed emergence percentage of snail medic in a) distilled water, b) domestic water, c) saline water, d) wastewater and e) purified water treated by magnetic field (250 mT).

Figure 4 shows the impact of magnetically-treated water on various parameters including seed emergence percentage, the number of emerged seeds, mean emergence time, emergence index, and emergence rate index. It was found that the magnetically treated water had the potential for rapid emergence and mean emergence time reduction for snail medic seeds (Fig. 4 a-b).

The significant effects of magnetically treated water was also observed on emergence indicators for various water types. Seed emergence percentage with magnetically-treated purified water is less than the untreated water, whereas magnetic domestic water has no significant effect on seed emergence percentage (Fig. 4a). Higher value of emergence index and emergence rate index symbolized the uniform and quick emergence (Fig. 4d-e). In addition, high values of mean emergence time indicated more time taken, whereas lower values indicated less time taken for seed emergence. Genuinely, the use of magnetically treated water had more impacts on mean emergence time of snail medic seed (Fig. 4c).

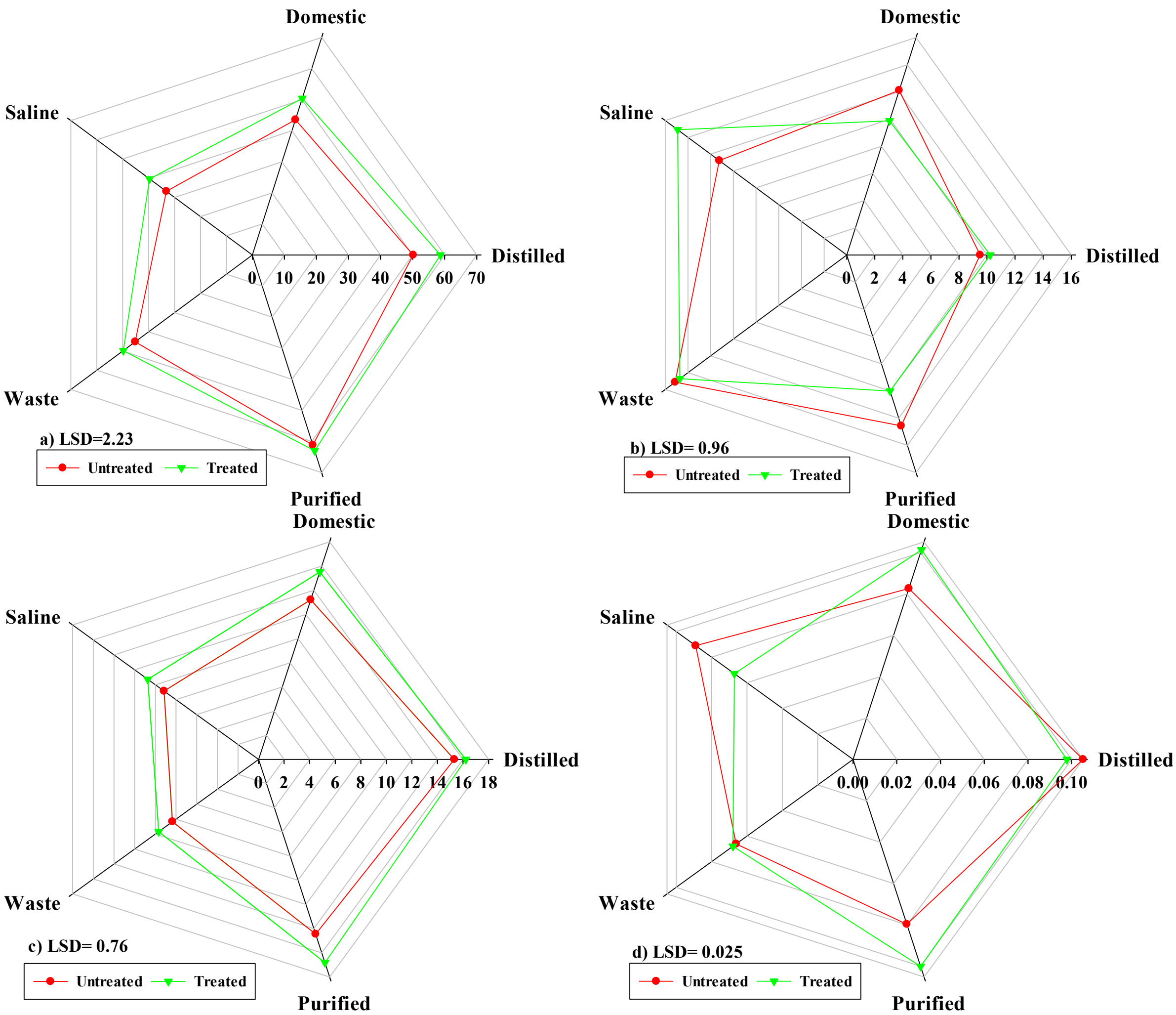

Figure 3 - Impact of various magnetically treated waters on a) weight of emerged seeds (g), b) time to 50 percent emergence (day), c) length of emerged seeds (cm) and d) seed emergence rate (mg d^{-1}) of snail medic

The results also demonstrated that the emergence index was increased from 16.2 to 18.28, 8.35 to 10.22, and 14.21 to 18.25 as well as emergence rate index, which increased from 9.23 to 10.41, 6.23 to 7.14, and 8.86 to 10.38 with magnetically-treated domestic water, wastewater and purified water, respectively (Fig. 4d-e). The value of mean emergence time was reduced from 8.6 to 8, 10 to 8.88, and 8.89 to 8.35 for domestic water, saline water and wastewater, respectively. These results were reversed for distilled water treatment (Fig. 4c). According to Smirnov (2004), the positive effect of magnetic field on living cells and their vital action by the signal produced in water is the main reason for these changes. Emergence index showed 11.23, 18.26, and 22.13 percent increases in treatments by magnetically-treated water for domestic water, wastewater, and purified water from sewage in Arak, respectively. Emergence rate index showed increases in treated magnetically-treated water for domestic water (11.34%), saline water (6.63%), and purified water (14.71%) (Fig. 4d-e).

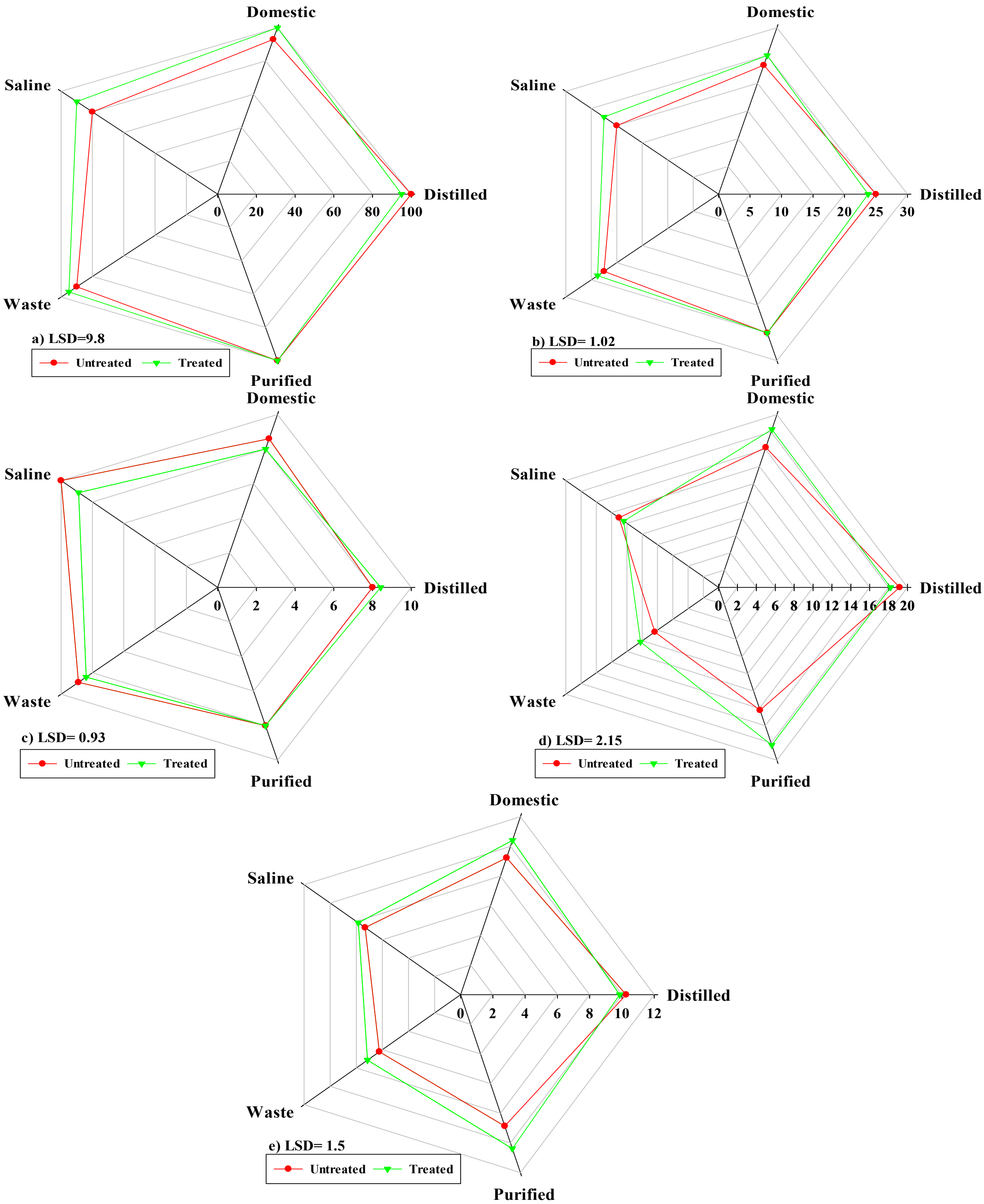

Figure 4 - Effect of magnetically treated water on a) seed emergence percent (%), b) number of emerged seeds, c) mean emergence time (d), d) emergence index and e) emergence rate index seedling emergence of snail medic

John et al. (2004) and Florez et al. (2007) concluded that the magnetically treated water may cause the separation of suspended particles from wastewater. However, Rameen and Younes (2011), Kotab (2013), and Hasaani et al. (2015) concluded when water is magnetized, such chemical parameters as TDS and EC experienced degradation of 33 and 36 percent, respectively. In addition, the pH parameter showed an upgrade of 12 percent. This phenomenon needs to define the term "saturation time", so that if circulation time is greater than the saturation time, the water is the saturation (Shahin et al., 2016).

The results confirmed that it may be due to some changes in the systematic biochemical level of the plant and their effects at cell level due to increase in water content. Based on several reports, the activation of ions and polarization of dipoles in living cells may affect magnetic fields. The dry weight of emerged seedlings in pots treated with magnetically-treated water, as compared with those in untreated pots (control treatment), showed increases for distilled water (13.65%), saline water (16.3%), wastewater (9.18%), and purified water (2.92%), respectively. The results for seedlings lengths in similar treatments increased by 5.54, 14.82, 14.67, 13.75, and 14.04 percent, respectively (*Johan et al*., 2004; *Shine and Guruprasad*, 2012; *Hachicha et al*., 2018).

Correlation analysis

Correlation between measured traits under different magnetically-treated water showed that there is positive and significant effect between dry weight of emerged seedlings with length of emerged seeds (0.74), seed emergence percent and number of emerged seeds (0.92), and emergence index (0.81). However, time to reach 50 percent emergence with emergence rate and number of emerged seeds with seed emergence percent have a highest coefficient value 0.98. Although there were positive and significant relation between emergence index with time to 50 percent, emergence rate, seed emergence percent and number of emerged seeds, seed emergence percent with weight of emerged seedlings and time to reach 50 percent, and number of emerged seeds with time to reach 50 percent and seed emergence percentage, and negative correlation was observed between time to reach 50 percent emergence with length of emerged seeds and emergence index (respectively -0.78 and -0.98) in various magnetically-treated waters (Table 2).

Table 2 - Pearson's correlation coefficients among measured traits: weight of emerged seedlings (WES), time to 50 percent emergence (TE_{50}), length of emerged seeds (LES), seed emergence rate (ER), seed emergence percent (SEP), number of emerged seeds (NES), emergence index (EI) and emergence rate index of snail medic.

Attributes	WES	TE_{50}	LES	ER	SEP	NES	EI	ERI
WES	1							
TE_{50}	-0.36$^{n.s}$	1						
LES	0.74*	-0.78**	1					
ER	0.37$^{n.s}$	-0.98**	0.79**	1				
SEP	0.92**	0.92**	-0.09$^{n.s}$	0.1$^{n.s}$	1			
NES	0.92**	0.93**	-0.1$^{n.s}$	0.1$^{n.s}$	0.98**	1		
EI	0.81**	0.82**	-0.05$^{n.s}$	0.33*	0.93**	0.92**	1	
ERI	-0.11$^{n.s}$	-0.13$^{n.s}$	0.19*	0.35*	-0.02$^{n.s}$	-0.17$^{n.s}$	0.19$^{n.s}$	1

n.s: not significant; (*) and (**) represent significant difference over control at $p < 0.05$ and $p < 0.01$, respectively

Conclusions

This study investigated the effects of different magnetically treated waters on emergence and growth of snail medic. The results showed when water is exposed to the magnetically-treated waters, the properties were changed. Based on the results, it was found that the pH increased significantly under different magnetically-treated waters, while EC and TDS decreased significantly by magnetic treatment. Therefore, the mobility of nutrient elements to the embryonic axis, and accordingly, the seed emergence percentage and emergence rate of snail medic seedlings are probably increased. However, it is difficult to interpret the experimental results using magnetically-treated water in various water sources, but seeds treated with magnetically-treated water as compared with those in untreated waters showed an improvement of 5-10 percent in the emergence percentage and a 5-14 percent and 2-16 percent increase in root length and seedling dry weight, respectively. In addition, for the snail medic seeds that only received pre-germination magnetic treatment, there was an increase of fresh weight and dry weight of shoots of 17 and 14 percent respectively, as compared to the untreated waters treatment. Thus, these experimental results verified that the magnetization of water is applicable in crop production.

Acknowledgement

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Data Availability

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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