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Modification of the greened house rye grass macro- and micronutrients uptake using magnetically treated water

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ABSTRACT

Two surface soils were selected (one saline and the other non-saline soil); in each soil five treatments of irrigation water were applied, of which the treatment with tap water served as the control, and a magnetic field was created by clamping a static magnet of 1.2 Tesla (12,000 Gauss) outside the irrigation pipe. Each treatment was replicated 4 times. Analyses were performed on the different parameters, and results showed that, relative to the control, there was an increase of 105.7% in the biomass yield only in the stage of plant stress, an increase in the uptake of N and P (79.5% and 141.1%, respectively), and an increase in the uptake of Zn, Cu and B (101.8%, 87.7% and 83.6%, respectively) by the use of the magnetic treatment. As for the total biomass and the total uptake of nutrients, no effect was noticed by the use of the magnetic treatment except for the total uptake of P (an increase of 70.3%). When using high salinity irrigation water with 2,000 mg/L NaCl, the only effect observed with the use of the magnetic treatment was on the uptake of N in the second cut (increase of 45.6%). Soil properties were also examined and results showed that with the use of the magnetic treatment there was a decrease of 13% in soil electrical conductivity and a decrease in soil-available Cu and Fe (15.8% and 45.2%, respectively).

Keywords: Biomass yield; Magnetically treated water; Nutrient uptake; Rye grass

1. Introduction

Natural resources are in a very critical situation in the entire world due to the climatic changes and the excessive use of these non-renewable resources. The new trend nowadays is towards embracing the concept of sustainability in terms of saving tomorrow's resources, and science water treatment has become a more important need to fulfil the demand of water in all aspects of life, coupled with escalating energy costs [1–3]. Therefore, the urge to have an easy, inexpensive, non-pollutant method for treating water has arisen [4,5].

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Magnetic treatment of water involves the passing of water through a magnetic field. It is an inexpensive, environmentally friendly treatment with no energy requirements [6]. The effects of magnetism on water, however, are still a matter of controversial debate. The motivation to use this simple technology is because of the beneficial effects it is claimed to have to the industries utilizing water and to the agricultural sector, as well as to the human water supply [7,8].

There are many claims that magnetically treated water suppresses scale deposition on the inner surface of boilers, heat exchangers and pipelines [9]. In addition, several reports have been published that ascribe increased performance of magnetically treated water with regards to increased nutrient uptake and crop yields [10–12], leaching of soil salts and even health benefits [13,14].

Proponents of the beneficial effects of magnetically treated water claim that passing water through a magnetic field results in important changes in its molecular structure or its ability to form clusters due to hydrogen bonding [15,16]. In a magnetic field, magnetic force can break apart water clusters into smaller ones or even into single molecules. As a result, water can become more "active" and as a consequence can increase the solubility of minerals; if this water is introduced into the soil, it can help the translocation of nutrients to root cells and to all parts of the plant tissues [17,18]. In addition, magnetically treated water can help the leaching of salts from the soil, alleviating thus the harmful effects of saline soils [19,20].

On the contrary, there are strong arguments that the alleged changes in water properties due to magnetism and the beneficial effects of magnetically treated water [21,22] belong to the realm of pseudoscience or that the reported beneficial effects have not been able to be reproduced [23,24].

The magnetic field (MF) effect on water was first noticed in 1803 when large stones were placed in the bottom of soup and laundry kettles to keep them from swinging in windy weather. The mineral accumulation on the sides and bottoms of these kettles was noticeably different when the lodestone (which is a natural magnetic rock) was used: instead of the hard, rock-like scale formation, there was a soft, powdery substance that was easily brushed off [25,26]. According to Sultan et al. [27], Faraday was the first researcher who was seriously involved with magneto-chemistry, beginning in 1863. As for the development of treating irrigation water by a magnetic field, a pioneering contribution was made by Vermeiren, according to Bogatin et al. [28] and Huang et al. [29].

In many research papers, scale reduction was considered a very important result for the magnetic treatment of water which has the benefits of reducing energy losses and improving equipment efficiency [29–31]. As can be seen in the study of Wang et al. [32], the results indicated that magnetic treatment significantly influenced the deposition of calcium carbonate scale under the controlled physico-chemical conditions employed and it was concluded that pH plays an important role in the mechanism by which magnetic fields affect scaling in flowing systems [33,34].

In view of the above, the main objective of the current work is to study the effect of magnetically treated irrigation water on nutrient uptake by rye grass grown in pots in the greenhouse. There are, however, the following secondary objectives, posed in the form of questions:

- Can the magnetic treatment of irrigation water make some difference in a saline soil in comparison to a non-saline soil? (With respect to plant growth and nutrient uptake).
- Can the magnetic treatment alleviate the undesirable effects of high salinity irrigation water? (With respect to plant growth and nutrient uptake).

2. Materials and methods

2.1. Soils, irrigation water and magnets

Two surface soils were selected (about 150 kg), one saline and the other non-saline. Treatment of soils included the usual pre-treatment (homogenization, removal of stones and plant tissues, air-drying). A great part of the raw soil was passed through a 6 mm sieve and about 130–140 kg of this size soil was collected. This is the material for the biological experiment (filling the pots and sowing with ryegrass). From this material, one part passed through a 2 mm sieve and about 2–3 kg of less than 2 mm soil was collected. In this "fine earth" soil characterization analyses are performed. Static magnets of 1.2 Tesla (12,000 Gauss) are used to create the magnetic field through which the irrigation water will pass.

2.2. Soil analyses

The following chemical analyses were performed in the two types of soil (saline and non-saline soils) before sowing to determine their properties prior to applying the treatments:

- pH in 1:2 soil to water ratio, using an electronic pH-meter [35].
- Electrical conductivity (EC) of the saturation extract, using a conductivity meter [36].
- Ca, Mg, K, Na in the saturation extract by ICP-AES [37].
- HCO_3^-, Cl and SO_4^{2-} in the saturation extract, according to AOAC [38].
- $CaCO_3$, by the volumetric calcimeter method [39].
- Organic matter (OM) by the wet oxidation method [40].
- Particle-size analysis [41].
- CEC by the hexamminecobalt trichloride method (ISO 23470) [42].
- Exchangeable cations K^+, Na^+, Ca^{2+} and Mg^{2+} by ammonium acetate 1N extraction [43].
- Micronutrients: Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+}, by DTPA-TEA extraction [44].
- NO_3–N by 1N KCl extraction and quantitative determination of nitrates colorimetrically [45].
- Boron, by hot-water extraction [46].
- Available P (Olsen-P) by sodium bicarbonate extraction [47]. Quantitative determination of P in the extract was done colorimetrically by forming a phosphoromolybdate complex and its subsequent reduction with ascorbic acid [48].

Quantitative determination of exchangeable and soluble cations and micronutrients in the extracts was done by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES), using a Leeman Labs Inc, PS 1000 AT instrument.

2.3. Biological experiment and experimental design

There are two types of soil were a saline and a non-saline soil with the conductivity of the saturation equal to 4.9 and 0.5 μS/cm, respectively. In each soil the following treatments of irrigation water were applied as coded in Table 1.

- T = tap water, without magnets (this will serve as the control) and with magnets;
- D = distilled water, with and without magnets.

The static magnets of 1.2 Tesla (12,000 Gauss) were clamped outside the irrigation pipes in the middle of each line; therefore the pots before the magnets were non-magnetically treated, and the pots after the magnets were magnetically treated. Each treatment was replicated 4 times, thus the total number of pots was 80 pots, placed in a completely randomized design.

Each pot, in a plastic dish, was filled with 1.5 kg of soil and 1 g of rye-grass seeds, sown in each pot. Therefore, 40 pots were filled with saline soil and 40 pots were filled with non-saline soil. The pots were sub-irrigated to field capacity by placing the treatment water in the plastic dish. The soils were kept at or near field capacity during the experiment by maintaining a 2 cm depth of water in each dish [49]. This water was changed every 24 h in the pots where magnetic fields had been applied, because the properties which the water gains after treatment in a magnetic field are lost after this period of time [50,51].

2.4. Plant tissue analyses

Above-ground material (approximately 1cm from the soil surface) was harvested at approximately 30-d intervals. The biomass was collected in a paper bag (of known weight), dried in an oven as soon as possible after collection, at 65°C for 48 h, weighed, ground to a suitable powder and stored in a jar. The biomass of each pot was assayed for N, K, P, Fe, Zn, Cu, Mn and B according to the following methods:

- Total N by the Kjeldahl procedure [52].
- Total P, K, Ca, Mg, Fe, Zn, Mn, Cu, B after decomposing the material by the dry-ashing method [53], and dissolving the ash in diluted HCl. Quantitative determination of elements was done by ICP-AES [37].

2.5. Statistical analysis

Data evaluation was done by a multi-way analysis of variance, using the pertinent statistical software. Comparisons between means are made by the least significant difference (LSD) at $p \leq 0.05$. A *t*-test was also performed when pertinent, between pairs of variables following Dutilleul et al. [54].

3. Results and discussion

The collected soils were analyzed for their physico-chemical parameters before sowing the rye grass and the results are presented in Table 2. Soil samples were also analyzed for their available nutrients and the results are presented in Table 3. Nevertheless, tap water analysis results are presented in Table 4.

3.1. Non-saline soil

To answer the first objective of this work, an ANOVA test was conducted to compare the total biomass yield of rye grass between the magnetically treated water and non-magnetically treated water used to irrigate plants in the non-saline soil, but the test showed no significant difference

Table 2
Physico-chemical parameters of the soils studied at the beginning of the experiment

		Non-saline soil	Saline soil
pH		8.7	8.1
EC, mS/cm		0.5	4.9
Ca^{2+}		60.8	728.3
K^+		13.4	42.6
Na^+		13.6	185.7
Mg^{2+}	mg/L	9.6	185.0
HCO_3^-		201.1	228.1
Cl^-		–	294.9
SO_4^{2-}		44.1	1115.8
CEC, cmolc/kg		17.7	19.5
$CaCO_3$		36.6	35.0
Organic matter		2.3	2.6
Sand	%	20.7	17.3
Clay		22.0	26.7
Silt		24.0	22.7

EC, Ca, K, Na, Mg, HCO_3, Cl and SO_4 were measured in the saturation extract.

Table 1
Treatments coding

	A: Saline soil		*B*: Non-saline soil	
	Without magnetic field	With magnetic field, M	Without magnetic field	With magnetic field, M
Tap water, T	AT	MAT	BT	MBT
Distilled water, D	AD	MAD	BD	MBD

Table 3
Available nutrients, in mg/kg of soil, in the two soils studied at the beginning of the experiment

	Non-saline soil	Saline soil
K^+	402.8	469.7
Fe^{2+}	7.0	6.8
Mn^{2+}	11.0	17.7
Zn^{2+}	1.2	3.1
Cu^{2+}	2.3	2.1
NO_3–N	0.6	38.5
HBO_3^{2-}	0.2	0.2
PO_4–P	8.8	68.8

Table 4
Results of tap water analyses

	μS/cm	mg/L						
pH	EC	HCO_3^-	Cl^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
8.4	994	283.8	112.0	50.0	68.2	7.1	86.4	15.6

Table 5
Biomass yield, in g/kg of soil, in non-saline soil as an average of the four replications

Cut	Treatments			
	BT	MBT	BD	MBD
1st	0.63	0.63	0.58	0.55
2nd	0.93	1.42	0.93	1.04
3rd	0.52	1.07	0.51	0.54
Total	2.08	3.11	2.02	2.13

in the total biomass yield by the use of the magnetic treatment [55]. By conducting the same test using the yields of the various cuts, it was found that only in the third cut was there a significant difference between the means of the MBT and BT treatments, while for BD and MBD there was no significant difference (Table 5). Thus, it seems that only when the plants are at stress (as they are after the 3rd cut) did the use of the magnetic treatment of tap water cause a significant increase (105.7%) in the biomass of rye grass [55,56].

To assess the effect of the magnetic treatment of irrigation water on nutrient uptake by rye grass, the results of macronutrient uptake are presented in Table 6. The ANOVA test showed a significant difference in total P uptake between BT and MBT treatments, as there was an increase of 70.3% in total P uptake, while for BD and MBD there was no significant difference in the total uptake of P (Table 7). As for total uptake of N and K, there were no significant differences observed by the use of the magnetic treatment [57,58].

Results of micronutrient uptake are presented in Table 8. The ANOVA test showed no significant difference by the use of the magnetic treatment of irrigation water on the total uptake of the micronutrients. But by conducting

Table 6
Uptake of N, P and K, in mg/kg of soil, by plants grown in the non-saline soil. Values for each cut are the average of the four replications

Nutrient	Cut	Treatments			
		BT	MBT	BD	MBD
N	1st	12.82	13.15	9.83	12.64
	2nd	18.45	24.32	14.27	15.37
	3rd	12.46	22.36	15.47	10.71
	Total	43.73	59.83	39.57	38.72
P	1st	0.37	0.50	0.12	0.14
	2nd	0.20	0.35	0.25	0.31
	3rd	0.17	0.41	0.16	0.21
	Total	0.74	1.26	0.53	0.66
K	1st	9.28	11.53	8.62	8.96
	2nd	10.53	17.57	14.08	16.29
	3rd	4.49	11.06	6.87	6.54
	Total	24.3	40.16	29.57	31.79

Table 7
Effect of the various treatments on macronutrients uptake, in mg/kg of soil, in the non-saline soil, in the various cuts

	Treatment	1st cut	2nd cut	3rd cut
N uptake	BT	12.82 a	18.45 ab	12.46 a
	MBT	13.15 a	24.32 b	22.36 b
	BD	9.83 a	14.27 a	15.47 ab
	MBD	12.64 a	15.37 a	10.71 a
P uptake	BT	0.37 b	0.20 a	0.17 a
	MBT	0.50 b	0.35 a	0.41 b
	BD	0.12 a	0.25 a	0.16 a
	MBD	0.14 a	0.31 a	0.21 ab
K uptake	BT	9.28 a	10.53 a	4.49 a
	MBT	11.53 a	17.57 a	11.06 a
	BD	8.62 a	14.08 a	6.87 a
	MBD	8.96 a	16.29 a	6.54 a

Means followed by the same letter are not statistically different, using the LSD test, $p \leq 0.05$.

Table 8
Total uptake of micronutrients, in mg/kg of soil, by plants grown in the non-saline soil. Values represent the sum of the three cuts

Micronutrient	Treatments			
	BT	BT	BT	BT
Fe^{2+}	0.21	0.16	0.12	0.12
Zn^{2+}	0.03	0.05	0.04	0.04
Mn^{2+}	0.20	0.30	0.21	0.24
Cu^{2+}	0.02	0.03	0.02	0.02
B	0.09	0.14	0.08	0.07

the same test on the micronutrients uptake of the various cuts, it was noticed that in the third cut, there were significant differences between the means of MBT and BT treatments in the uptake of Zn, Cu and B, while for BD and MBD there were no significant differences [59]. As for Fe and Mn there were no significant differences observed by the use of the magnetic treatment. Thus, only when the plants were at stress (as they are after the 3rd cut) did the use of the magnetic treatment on tap water cause an increase in the uptake of Zn, Cu and B; this increase reached 101.8%, 87.7% and 83.6%, respectively [55,57].

By conducting the same test using the yields of the various cuts, it was found that only in the third cut was there a significant difference between the means of the MBT and BT treatments, while for BD and MBD there was no significant difference (Table 9). Thus, it seems that only when the plants are at stress (as they are after the 3rd cut) did the use of the magnetic treatment of tap water cause a significant increase (105.7%) in the biomass of rye grass.

3.2. Saline soil

The effect of the magnetic treatment on the biomass yield of rye grass grown in saline soil was studied to answer the secondary objective of this work. Results of the biomass yield of rye grass in saline soil are presented in Table 10, as an average of the four replications for each one of three cuts. Results of macronutrient uptake by plants grown in saline soil are presented in Table 11. The results of the ANOVA test showed no significant difference in total macronutrients uptake. The biomass of each pot of the saline soils were examined for N, K, P, Fe, Zn, Cu, Mn and B are presented in Table 12.

The ANOVA test showed no significant difference in the total biomass yield by the use of the magnetic treatment. By conducting the same test on the various cuts, no significant effect was also observed on the biomass yield of rye grass grown in saline soil by the use of the magnetic treatment (Table 13). By conducting the same test on the various cuts, no significant effect was also observed in macronutrients uptake by the use of the magnetic treatment (Table 14). Thus, when rye grass is grown in saline soil, the magnetic treatment of irrigation water did not have an effect on macronutrients uptake [55,60].

Table 9
Effect of the various treatments on biomass yield, in g/kg soil, in the non-saline soil, in the various cuts

Treatment	1st cut	2nd cut	3rd cut
BT	0.63 a	0.93 a	0.52 a
MBT	0.63 a	1.42 a	1.07 b
BD	0.58 a	0.93 a	0.51 a
MBD	0.55 a	1.04 a	0.54 a

Means flowed by the same letter are not statistically different, using the LSD test, $p \leq 0.05$.

Table 10
Biomass yield, in g/kg of soil, in saline soil as an average of the four replications

Cut	Treatments			
	AT	MAT	AD	MAD
1st	0.79	0.90	0.82	0.74
2nd	2.08	2.11	2.20	2.34
3rd	0.93	1.23	1.38	1.63
Total	3.80	4.23	4.40	4.71

Table 11
Uptake of N, P and K, in mg/kg of soil, by plants grown in the saline soil. Values for each cut are the average of the four replications

Nutrient	Cut	Treatments			
		AT	MAT	AD	MAD
N	1st	23.64	23.40	29.87	27.68
	2nd	24.95	25.57	23.37	27.34
	3rd	14.71	14.36	16.64	28.54
	Total	63.3	63.33	69.88	83.56
P	1st	1.54	1.81	0.58	0.58
	2nd	1.21	1.18	1.67	1.91
	3rd	0.63	0.74	1.06	1.20
	Total	3.38	3.73	3.31	3.69
K	1st	13.24	14.41	15.28	14.76
	2nd	20.49	21.03	30.62	36.70
	3rd	9.70	10.21	15.75	22.01
	Total	43.43	45.65	61.65	73.47

Table 12
Total uptake of micronutrients, in mg/kg of soil, by plants grown in the saline soil. Values represent the sum of the three cuts

Micronutrient	Treatments			
	AT	MAT	AD	MAD
Fe^{2+}	0.15	0.25	0.26	0.26
Zn^{2+}	0.07	0.07	0.09	0.11
Mn^{2+}	0.51	0.60	0.47	0.44
Cu^{2+}	0.03	0.03	0.04	0.05
B	0.18	0.19	0.22	0.20

Table 13
Effect of the various treatments on biomass yield, in g/kg soil, in the saline soil, in the various cuts

Treatment	1st cut	2nd cut	3rd cut
AT	0.79 a	2.08 a	0.39 a
MAT	0.90 a	2.11 a	1.23 a
AD	0.82 a	2.20 a	1.38 a
MAD	0.74 a	2.34 a	1.63 a

Means flowed by the same letter are not statistically different, using the LSD test, $p \leq 0.05$.

Table 14
Effect of the magnetic treatment of water on macronutrients uptake, in mg/kg of soil, in the saline soil, in the various cuts

	Treatment	1st cut	2nd cut	3rd cut
N uptake	AT	23.64 a	24.95 a	14.71 a
	MAT	23.40 a	25.57 a	14.36 a
	AD	29.87 a	23.37 a	16.64 a
	MAD	27.68 a	27.34 a	28.54 a
P uptake	AT	1.54 b	1.21 a	0.63 a
	MAT	1.81 b	1.18 a	0.74 a
	AD	0.58 a	1.67 a	1.06 a
	MAD	0.58 a	1.91 a	1.20 a
K uptake	AT	13.24 a	20.49 a	9.70 a
	MAT	14.41 a	21.03 a	10.21 a
	AD	15.28 a	30.62 a	15.75 a
	MAD	14.76 a	36.70 a	22.01 a

Means followed by the same letter are not statistically different, using the LSD test, $p \leq 0.05$.

3.3. Comparisons

A comparison between the two soils in total biomass yield, in g/kg of soil, and in total macronutrients uptake, in mg/kg of soil, was conducted by the use of the *t*-test to answer the secondary objective about the ability of MT in irrigation water to make a difference in the saline soil in comparison to non-saline soil.

3.3.1. Biomass yield

A paired sample *t*-test was conducted to compare the biomass yield between saline and non-saline soil. Results showed that there was no significant difference in biomass yield between the two soils either with or without the presence of the magnetic treatment [61,62]. Thus the magnetic treatment of irrigation water did not make a difference in the saline soil in comparison to the non-saline soil regarding biomass yield (Table 15).

3.3.2. Macronutrient uptake

By conducting the *t*-test to compare total macronutrients uptake between saline soil and non-saline soil, results showed that there was a significant difference in total N uptake between saline and non-saline soil in the distilled water treatment [63]. With the presence of the magnetic treatment, total N uptake was significantly greater in MAD than in MBD, while in the absence of the magnetic treatment there was no difference between the two soils in N uptake [64]. As for total P and K uptake there was no significant difference between the means of the two soils either with or without the magnetic treatment (Table 16). The magnetic treatment made a difference in the saline soil in comparison to non-saline soil regarding total N uptake when plants were irrigated with distilled water [65,66].

Results showed that the positive effect by the use of the magnetic treatment on yield was only accomplished at the stage of plant stress and not for the total biomass yield, while in the work of Hozayn and Qados [67] the total yield improvement by the use of the magnetic treatment was substantiated for chickpea in seed, straw and biological yield per plant. Bogatin et al. [28], also showed an increase of total yield by 15% for grain, fodder, vegetables, and melon-field crops with simultaneous improvement of production quality.

Table 15
Difference between the means of each pair for the total biomass yield for tap water and distilled water

Biomass g/kg of soil	Difference between the means
AT-BT	0.57
MAT-MBT	0.37
AD-BD	0.79
MAD-MBD	0.86

Table 16
Difference between the means of each pair for macronutrients total uptake, in mg/kg of soil, in tap water and distilled water treatments

	Difference between the means		
	N	P	K
AT-BT	6.52	0.88	6.38
MAT-MBT	1.17	0.82	1.83
AD-BD	10.10	0.93	10.69
MAD-MBD	14.95	1.01	13.89

In the work of Shabani et al. [68], the magnetic treatment of irrigation water caused a significant increase in P concentration in celery shoots, while in the work of Aliverdi et al. [69] there was a significant increase in N content in snow pea and chickpea seedling by the use of the magnetic treatment. In the current study there was a significant increase in total P uptake by the use of the magnetic treatment having P uptake in the third cut as the major contributor to this significant increase, while for N uptake the effect of the magnetic treatment was only observed at the third cut (the stage of plant stress).

The magnetic treatment reduced the induction time, and there was a steep increase in turbidity which indicated great acceleration in the nucleation and crystallization process. But some articles did not yield a positive result for using magnetic fields as a scale reduction procedure. For example, according to Hasson and Bramson [70], the treatment showed no effect on the deposit growth, nor any effect on the adhesive nature of the deposits.

Contradictory results were obtained when magnetically treated water (MTW) was used in experiments. Many research papers claimed that treating water with a magnetic field can improve its chemical and physical properties; thus it can affect the efficiency and productivity of irrigation water and improve scale reduction in heating systems [71–73]. On the other hand, some publications in peer-reviewed journals reported adverse results about magnetically treated water and disputed its benefits [74–76].

In the study of Alimi et al. [31], the effect of a permanent magnetic field on calcium carbonate precipitation type (homogeneous and heterogeneous) and solubility was studied. When the MTW was exposed to a scaling test by degassifying dissolved CO_2 in water, it was found that magnetic treatment increased the total amount of precipitate and favored the homogeneous nucleation depending on water pH, water flow rate and the time of exposure to magnetic field [77,78].

As a conclusion it can be stated that although the mechanisms through which magnetically treated water operates are not well understood, its reported beneficial effects cannot be ignored but should be tested [79], particularly in the field of agriculture. Magnetic treatment of water should not be a case of "once proved correct, then we shall study it", but a case of "we should study this till we prove it does not work" as it was concluded by Mehta et al. [80].

4. Conclusions and recommendations

The results of this work showed that when tap water was magnetically treated there was a significant increase of 105.7% (relative to the control of plain tap water) in the biomass yield of rye grass grown in non-saline soil, but only when the plants were at stress (as they were at the 3rd cut), while no significant effect was observed for the total biomass yield, and when plants were irrigated with magnetically treated saline water (with 2,000 and 5,000 mg/L NaCl). Also, no effect on the biomass yield was noticed.

The use of the magnetic treatment of tap water caused a significant increase in the uptake of N and P when the plants were at stress (as they were in the 3rd cut). This increase in the uptake of N and P in the third cut reached 79.5% and 141.1%, respectively. The magnetic treatment of tap water also caused a significant increase of 70.3% in the total P uptake. A significant effect on the uptake of Zn, Cu and B at the stage of plant stress (in the 3rd cut) was also noticed by the use of the magnetic treatment of tap water, which amounted to an increase of 101.8%, 87.7% and 83.6% in the uptake of Zn, Cu and B, respectively. The magnetic treatment reduced the bad effect of high salinity irrigation water (with 2,000 mg/L NaCl) on the uptake of N and there was an increase of 45.6% in N uptake in the second cut, while for the higher salinity level with 5,000 mg/L NaCl no effect was observed on N uptake. As for the uptake of P, K and the micronutrients, the magnetic treatment did not alleviate the undesirable effect of high salinity irrigation water.

The magnetic treatment of irrigation water did not have an effect on soil pH, as well as when using irrigation water with high concentrations of bicarbonates. There was a significant decrease of 13% in soil EC by the use of the magnetic treatment on tap water, while with the presence of high concentrations of bicarbonates in water the magnetic treatment did not have an effect on soil EC. The magnetic treatment of tap water caused a significant decrease in soil available Cu and Fe (15.8% and 45.2%, respectively), but it did not have an effect on soil-available Zn, Mn, B nor on soil available macronutrients.

When the soil was saline (4.9 mS/cm), no effect was observed on the total biomass yield nor on the total macronutrient uptake by the use of the magnetic treatment on irrigation water. When the two soils were compared, the results showed that the magnetic treatment did not cause a difference between saline soil and non-saline soil regarding biomass yield. But the use of the magnetic treatment of distilled water caused a significant difference between saline soil and non-saline soil in total N uptake, while there was no difference between the two soils in total N uptake by the absence of the magnetic treatment. Thus, it is concluded that the magnetic treatment of irrigation water had effects on some parameters, but the conditions in which the magnetic treatment could be more effective have to be studied in further works.

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