USAGE OF MAGNETIC IRON TO RAISE TOLERANCE OF SOME ORNAMENTAL TREES AND SHRUBS TO SOIL SALINITY IN CASE OF HORSERADISH TREE (*MORINGA OLEIFERA* LAM.)

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Abstract. An experiment was performed at Orman Botanical Garden, Giza, Egypt to determine the role of magnetite ore at either 2 or 4 g/pot in reducing the harmful effects of soil salinity on growth and quality of *Moringa oleifera* Lam. grown in soil mixture salinized with a mixture of NaCl and $CaCl_2$ salts at concentrations of 0, 2000, 4000, 6000 and 8000 ppm. The effect of the interaction between salinity and magnetite was also studied. The results indicated that a gradual decrease in survival percentage was observed with the gradual increments in salinity, but it was progressively increased with higher magnetite rates irrespective of salinity concentration. Connecting between magnetite at any dose and salinity up to 4000 ppm gave the highest percentage of survival rate in the two seasons. While, the lowest survival rate was recorded at 8000 ppm, especially in the absence of magnetite. A response similar to that of survival percentage occurred for vegetative and root growth traits, and leaf chemical composition, with few exceptions in both seasons. Thus, it is advised to drench soil mixture with magnetite at 4 g/pot to enhance growth and quality of *Moringa oleifera* transplants under salt stress.

Keywords: *salinity, Moringa oleifera, magnetite, carotenoids, proline*

Introduction

Among many species included in Fam. *Moringaceae* is considered the miracle species having tremendous uses, such as aforestation, alley cropping, medicines, water purification biopesticides, biogas, green manure and gum production, domestic cleaning agent and as a vegetable for their edible roots, young leaves, fruits and seeds, from which oil is often extracted (Aiyelaagbe, 2011). It grows rapidly up to 9-10 m height in poor soil with little care for long periods of drought (McConnachie, 1999). It is originated in India and Pakistan, but is now distributed to most tropical areas as ornamental, fodder, fibrous, malnutrition solving and economic plant (Fahey, 2005; Thurber and Fahey, 2009). It is easily propagated by seeds and stem cuttings, tolerates a wide range of soil conditions, but prefers a neutral to slightly acidic (pH 6.5-7), well drained sandy or loamy soils. It is considered as drought resistant, but water logging sensitive (Suein, 2008).

Regarding salinity tolerance of *Moringa oleifera,* Dos Santos et al. (2011) noticed that the gradual increase in NaCl concentration (0, 25, 50, 100, 200 and 250 mol/m^3) caused a gradual decrement in germination % germination speed index and seedling length. Moreover, Nouman et al. (2012a) reported that moringa seedlings survived up to 3500 ppm NaCl salinity with a slight reduction in its biomass, chlorophyll a, crude protein and mineral concentrations. Activity of superoxide dismutase (SOD) and peroxidase (POD) and Ca, K and Mg concentrations were progressively decreased, but

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catalase (CAT), total phenols, chlorophyll b, β-carotene, Na and P concentrations were significantly increased with raising salinity up to 5500 ppm relative to control. Similarly, were those results of Nouman et al. (2012b), Rivas et al. (2013) and Elhag and Abdalla (2014) on *Moringa oleifera*.

The deleterious effects of salinity on ornamentals, such as reduction of plant growth and leaf yellowing, browning of the leaf tips and margins, defoliation, root shortening and may ultimately plant die were previously suggested by Al-Qubaie et al. (2003) on *Bongainvilleaglabra*, *Conocarpus erectus*, *Ficus benghalensis*, *Jasminum azoricum*, *Tamarix articulata* and *Ziziphus spina-christi*, Shahin et al. (2008) on *Ficus macrocarpa*var. Hawaii and *Euonymus Joponica* cv. Mediopicta, Shahin et al. (2013) on *Ficus benjamina cv. Samantha and Schefflera arboricola* cv. Gold Capella, El-Fouly et al. (2015) on *Iris tingitana* cv. Wedgewood, Jose et al. (2016) on *Eucalyptus urophylla* and Shahin et al. (2017) on *Casuarina equisetifolia* and *Eucalyptus rostrata*. However, these harms were minimized by some practical methods, such as those revealed by Moustafa et al. (2017) on *Moringa oleifera* using magnetic iron. The role of magnetite in reducing hazards of salinity was also documented by Abdel-Fattah (2014) on *Jacaranda acutifolia*, Ahmed et al. (2016) on *Acalypha wilkesiana*, Shahin et al. (2018) on *Terminalia arjuna* and El-Sayed et al. (2019) on *Enterolobium contortisiliquum*.

Such trial, however aims to evaluate the role of magnetic iron in reducing the harmful effects of soil salinity on growth and quality of *Moringa oleifera* transplants during rearing period in the nursery.

Materials and methods

The current study was conducted in the full sun the average temperature between (27-38ºC) and the average percentage of humidity 56% at the nursery of Orman Botanical garden, Giza, Egypt throughout the two successive seasons of 2018 and 2019 as an attempt to verify the benefit of magnetite in minimizing the hazards of soil salinity on growth and quality of moringa transplants, and to detect its role in helping these nurslings to grow well under such stress.

Thus, 4-months-old, uniform transplants of the plant at a length of about 30 cm with 3-4 leaves were transplanted on April, 1st for every season to 15-cm-diameter polyethylene black bags (one seedling/bag) filled with about 3.5 kg of sand and clay mixture at equal volume parts (1:1, v/v). The physical and chemical properties of the soil mixture used in the two seasons were determined and illustrated in *Table 1*.

Table 1. *The physical and chemical analysis of the soil mixture used in 2018 and 2019 seasons*

Soil mixture	**Particle size distribution (%):**				**S.P.**	**E.C. (dS/m)**	**pH**	**Cations (meq/l)**			
Sand + Clay (1:1, v/v)	Coarse sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}
	38.6	31.3	20.6	9.5	25	6.5	7.86	17.8	14.2	33.1	0.9
Soil texture	**Anions (meq/l)**				**Macro-and micro-elements (ppm)**						
	HCO_3^-	Cl^-	SO_4^{--}	CO_3	N	P	K	Fe	Zn	Mn	Cu
Sandy clay	2.10	58.40	5.50	0.00	173.10	15.78	361.76	15.80	4.36	8.03	8.81

Immediately before transplanting, the above soil mixture was salinized with an equal mixture of NaCl and $CaCl_2$ pure salts (1:1, by weight) at the concentrations of 0, 2000, 4000, 6000 and 8000 ppm. After planting, however the soil mixture was thoroughly drenched with magnetic iron (Fe_3O_4, 22.5%) secured from Alahram Mining Co., Maadi, Cairo at the rates of 0, 2 and 4 g/plant, as one batch at the beginning of the season. Each level of salinity was combined with each one of magnetic iron to formalize 15 interaction treatments.

The transplants under various experimental treatments were fertilized 3 times during the course of this study with 2 g/transplants of NPK + micro elements chemical fertilizer (Kristalon, 19:19:19) and watered every other day. Furthermore, all the other agricultural practices needed for such plantation were done as usually grower did. A factorial in complete randomized design with 3 replicates, as each one contained 5 seedlings was used in every season (Mead et al., 1993).

Data recorded, at the end of each season (on October, 1st), were: survival (%), plant height (cm), stem diameter (cm), number of leaves/plant, leaf length (cm), the longest root length (cm), root collar diameter (cm), aerial parts and roots fresh and dry weights (g) and salt resistance index as a percentage (SRI %) was calculated from the equation of Wu and Huff (1983) as follows:

$$\text{SRI (\%)} = \text{Mean root length of the longest root in salt treated plant / mean root length of the longest root in control one x 100} \quad \text{(Eq.1)}$$

In addition, the benefit coefficient of magnetite (Fe_3O_4) under various salinity levels as a percentage (B. Coe %) was estimated from the following equation:

$$\text{B. Coe (\%)} = \text{Increase rate in dry matter of treated plant / dry matter of control one x 100.} \quad \text{(Eq.2)}$$

In fresh samples concentrations of photosynthetic pigments (chlorophyll a, b and carotenoids, mg/g f.w.) were determined according to the method of Sumanta et al. (2014), while in dry ones the percentages of nitrogen (Blake, 1965), phosphorus (Luatanab and Olsen, 1965), as well as potassium, sodium and chloride (Jackson, 1973) were measured. Concentration of the free proline (mg/100 g d.w.) was also assessed in dry leaf samples by the method of Batels et al. (1973). The abovementioned constituents were evaluated in the second season only.

Data were then subjected to analysis of variance using the computer program of SAS Institute (2009), followed by Duncan's New Multiple Range t-Test (Steel and Torrie, 1980) for means comparison.

Results

Effect of soil salinity, magnetite and their interaction on vegetative and root growth parameters

Data presented in *Table 2* show that survival % means were descendingly decreased with increasing salinity level to reach the minimum at 8000 ppm level in both seasons, but progressively increased with rising magnetite rate to be maximum at 4 g/plant rate regardless of salinity level. Combining between any dose of magnetic iron and salinity up to 4000 ppm gave the highest survival percentage in the two seasons. A significant reduction in means of this character was observed when salinity level was elevated to 6000 ppm, but it was still higher than 50% in most cases of both seasons especially in the presence of magnetite. The least records however were attained by 8000 ppm salinity level, even in the presence of Fe_3O_4, but it`s absence greatly reduced means of such trait to 27.4% in the first season and to 00.00% in the second one due to death of the plants.

Table 2. *Effect of salinity levels, magnetite rates and their interactions on survival and height of Moringa oleifera Lam. transplants during 2018 and 2019 seasons*

Fe_3O_4 rate (g/plant) / **Salinity level (ppm)**	**Survival (%)**				**Plant height (cm)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018							
0.00	100.00a	100.00a	100.00a	100.00A	94.67d	103.0b	108.9a	102.2A
2000	100.00a	100.00a	100.00a	100.00A	92.00e	98.99c	102.6b	97.86B
4000	89.22b	100.00a	100.00a	96.41B	70.78i	78.93h	88.51f	79.41C
6000	53.17e	70.82d	76.91c	66.97C	62.12j	70.17i	83.11g	71.80D
8000	27.40g	35.17f	40.34f	34.30D	49.00l	55.73k	63.10j	55.95E
Mean	73.96C	81.20B	83.45A		73.71C	81.36B	89.25A	
	Second season; 2019							
0.00	100.00a	100.00a	100.00a	100.00A	86.50e	103.0b	114.4a	101.8A
2000	100.00a	100.00a	100.00a	100.00A	84.83ef	100.1c	102.2bc	95.71B
4000	73.33c	87.20b	100.00a	86.94B	76.67g	83.67f	94.43d	84.92C
6000	41.53f	58.30e	65.80d	55.21C	64.50i	73.90h	87.27e	75.22D
8000	0.00h	34.50g	38.30g	24.27D	0.00l	33.07k	36.10j	23.06E
Mean	62.97C	76.00B	80.82A		62.50C	79.01B	86.89A	

Mean followed by the same letter in a column or row don’t differ significantly according to Duncan’s New Multiple Range test

A similar trend to that of survival percentage was just obtained regarding plant height (cm), stem diameter (cm), No. leaves/plant, leaf length (cm), root length (cm), root collar diameter (cm), as well as aerial parts and roots fresh and dry weights (g) attributes (*Tables 2, 3, 4, 5 and 6*), as the means of these traits were gradually decreased with increasing salinity levels, but progressively increased with raising magnetic iron rate. The highest averages were also recorded by the concentrations between salinity concentration up to 4000 ppm and any dose of magnetite. Increasing salinity level to 6000 ppm caused a significant reduction in the means of foregoing criteria, with the exception for plants which received Fe_3O_4 at any rate. The minimal values were however acquired by 8000 ppm salinity treatments especially for plants abandoned of magnetic iron.

Salt resistance index (SRI %) and benefit coefficient of magnetite (B. Coe. %).

It is clear from data presented in *Table 7* that percent of salt resistance index was linearly decreased as salinity concentration was increased. Thus, the least SRI value was achieved by 8000 ppm concentration to be 53.54% in the first season and 39.46% in the second one. Decrement mean of this index to less than 50% really indicates the low tolerance of moringa to salinity higher than 6000 ppm. Magnetite at the rate of 2 g/plant scored the highest percentages of SRI in the two seasons, followed by 4 g/plant rate. Under control treatment, a pronounced decline in the values of this index was acquired with increasing salinity level to be less than 50% in both seasons by 8000 ppm treatment. This confirms that moringa is not able to tolerate salinity higher than 6000 ppm as mentioned before. On the other side, application of Fe_3O_4 improved the means of such index to be higher than 50% even under 8000 ppm treatment, showing the important role of this natural ore in enhancing moringa tolerance to high salinity.

Table 3. *Effect of salinity levels, magnetite rates and their interactions on stem diameter and No. leaves/plant of Moringa oleifera Lam. transplants during 2018 and 2019 seasons*

Fe_3O_4 rate (g/plant) / **Salinity level (ppm)**	**Stem diameter (cm)**				**No. leaves /plant**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018							
0.00	0.797c	0.870b	0.947a	0.871A	7.07c	8.33b	9.67a	8.36A
2000	0.740d	0.830c	0.890b	0.820B	6.50d	8.50b	9.50a	8.17B
4000	0.683ef	0.737d	0.803c	0.741C	5.67e	7.17c	8.33b	7.06C
6000	0.577g	0.647f	0.693e	0.639D	3.83g	5.67e	6.50d	5.33D
8000	0.477i	0.497i	0.527h	0.500E	3.00h	4.00g	4.83f	3.94E
Mean	0.655C	0.716B	0.772A		5.21C	6.33B	7.77A	
	Second season; 2019							
0.00	0.750de	0.877b	0.930a	0.852A	7.33e	8.67c	9.67a	8.56A
2000	0.740de	0.837bc	0.863b	0.813A	5.33g	9.00c	9.33ab	7.89B
4000	0.660f	0.713e	0.793cd	0.722B	5.67g	7.00ef	8.00d	6.89C
6000	0.547g	0.627f	0.730e	0.634C	4.67h	5.67g	6.67f	5.67D
8000	0.00i	0.353h	0.387h	0.247D	0.00j	3.33i	4.67h	2.67E
Mean	0.539C	0.681B	0.741A		4.60C	6.73B	7.67A	

Mean followed by the same letter in a column or row don't differ significantly according to Duncan's New Multiple Range test

As for the benefit coefficient of magnetite percentage (B. Coe. %), as a real indicator for the advantage of magnetic iron in reducing hazards of salinity, with promoting plant growth, is presented in *Table 7* which exhibits that Fe_3O_4 significantly increased dry matter production of treated plants under the different salinity levels over control in the two seasons. However, the upper hand in the increased means of such coefficient in the first season was for magnetite under 2000 and 6000 ppm salinity treatments, as 31.88 and 31.27% against 15.97% for control, followed by magnetite under 4000 ppm level, while in the second season, that was true for magnetite under 8000 ppm level, which raised the percent of this coefficient to 259.0% versus 27.85% for control. Likewise, a progressive increment was occurred in the means of this coefficient with raising Fe_3O_4 rate. So, the greatest benefit of this ore was recorded in both seasons by 4 g/plant dose. Interaction treatments also encouraged dry matter production as applying Fe_3O_4 at 2 or 4 g/plant caused a significant increase in the production of dry matter over control regardless of salinity level in the two seasons.

Table 4. *Effect of salinity levels, magnetite rates and their interactions on leaf and root length and root callar diameter of Moringa oleifera Lam. transplants during 2018 and 2019 seasons*

Fe_3O_4 rate (g/plant) / **Salinity level (ppm)**	**Leaf length (cm)**				**Root length (cm)**				**Root callar diameter (cm)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018											
0.00	15.81g	14.94h	16.11fg	15.62C	13.44cd	13.97bc	16.19a	14.53A	1.87de	2.20c	2.37b	2.14B
2000	16.67ef	18.78d	20.50b	18.65A	12.49e	13.07d	14.37b	13.31B	1.80ef	2.40b	2.47b	2.22AB
4000	11.90i	19.45c	21.72a	17.69B	10.92f	11.44f	13.35d	11.91C	1.67fg	2.27b	2.67a	2.27A
6000	10.78j	16.06g	17.23e	14.69D	8.86h	9.93g	10.93f	9.91D	1.50g	1.92de	1.99d	1.80C
8000	9.03l	9.65k	10.80j	9.83E	6.10j	8.20i	9.05h	7.78E	1.27h	1.56g	1.61g	1.48D
Mean	12.84C	15.78B	17.27A		10.36C	11.32B	12.78A		1.62C	2.11B	2.22A	
	Second season; 2019											
0.00	15.55b	16.96a	17.25a	16.59A	12.50c	13.22b	15.36a	13.70A	2.20bc	2.24b	2.57a	2.34A
2000	14.19c	15.15b	17.28a	15.54B	11.44d	11.52d	13.45b	12.14B	2.02d	2.04cd	2.37b	2.14B
4000	13.06d	14.17c	15.25b	14.16C	10.16f	10.78e	13.00c	11.31C	1.79e	1.90de	2.31b	2.00C
6000	11.94e	11.42ef	14.00c	12.45D	8.31h	8.94g	10.03f	9.09D	1.45g	1.58fg	1.74ef	1.59D
8000	0.00h	8.06g	11.33f	6.47E	0.00i	8.11h	8.61gh	5.57E	0.00h	1.43g	1.48g	0.97E
Mean	10.95C	13.15B	15.02A		8.48C	10.51B	12.09A		1.49C	1.84B	2.09A	

Mean followed by the same letter in a column or row don't differ significantly according to Duncan's New Multiple Range test

Table 5. *Effect of salinity levels, magnetite rates and their interactions on aerial parts fresh and dry weights of Moringa oleifera Lam. transplants during 2018 and 2019 seasons*

Fe_3O_4 rate (g/plant) / **Salinity level (ppm)**	**Aerial parts fresh weights (g)**				**Aerial parts dry weights (g)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018							
0.00	13.64de	14.17d	19.44a	15.75A	6.37c-e	6.94c	8.48a	7.27A
2000	10.95f	15.19c	17.60b	14.58B	5.15f	6.98c	7.63b	6.59B
4000	9.80g	13.12e	15.44c	12.78C	4.59fg	6.06de	6.74cd	5.80C
6000	8.00h	11.10f	13.35e	10.82D	3.74hi	4.94fg	5.81e	4.83D
8000	6.62i	8.72h	9.98g	8.44E	3.10i	3.89h	4.34gh	3.78E
Mean	9.80C	12.46B	15.16A		4.59C	5.76B	6.60A	
	Second season; 2019							
0.00	11.48e	16.51c	19.75a	15.91A	6.14c	7.37b	9.40a	7.84A
2000	8.54g	16.76c	18.69b	14.66B	4.61d-f	8.18b	8.92a	7.24B
4000	8.88g	13.97d	16.07c	12.98C	4.75de	6.73c	7.64b	6.37C
6000	7.54h	10.88e	13.41d	10.61D	4.05f	5.25d	6.38c	5.23D
8000	0.00i	6.71h	9.54f	5.42E	0.00h	3.25g	4.52ef	2.59E
Mean	7.29C	12.97B	15.49A		3.91C	6.28B	7.37A	

Mean followed by the same letter in a column or row don't differ significantly according to Duncan's New Multiple Range test

Table 6. *Effect of salinity levels, magnetite rates and their interactions on roots fresh and dry weights of Moringa oleifera Lam. transplants during 2018 and 2019 seasons*

Fe_3O_4 rate (g/plant) / **Salinity level (ppm)**	**Roots fresh weights (g)**				**Roots dry weights (g)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018							
0.00	13.38e	22.38b	25.78a	20.51A	4.13f	7.99b	10.31a	7.48A
2000	13.81de	22.42b	25.73a	20.65A	4.28f	8.02b	10.25a	7.52A
4000	11.23f	18.97bc	20.39c	16.86B	3.46g	6.73c	8.13b	6.10B
6000	9.23gh	13.28e	15.33d	12.61C	2.85h	4.68e	6.12d	4.55C
8000	7.16j	8.38hi	10.62fg	8.72D	2.20i	2.98h	4.19f	3.13D
Mean	10.96C	17.09B	19.57A		3.38C	6.08B	7.80A	
	Second season; 2019							
0.00	11.63b-d	12.69b	14.03a	12.78A	2.96cd	3.42b	3.89a	3.43A
2000	10.65de	11.05c-e	12.20b	11.30B	2.71de	2.96cd	3.39b	3.02B
4000	9.48fg	10.23ef	11.84bc	10.52B	2.37e-g	2.70de	3.26bc	2.78C
6000	7.70hi	8.43gh	9.03g	8.39C	1.89h	2.25f-h	2.52ef	2.22D
8000	0.00j	7.39hi	7.30i	4.90D	0.00i	1.95h	2.01gh	1.32E
Mean	7.89C	9.96B	10.88A		1.99C	2.66B	3.02A	

Mean followed by the same letter in a column or row don't differ significantly according to Duncan's New Multiple Range test

Table 7. *Effect of salinity levels, magnetite rates and their interactions on resistance index and benefit coefficient of Moringa oleifera Lam. transplants during 2018 and 2019 seasons*

Fe$_3$O$_4$ rate (g/plant) Salinity level (ppm)	Salt resistance index (%)				Benefit coefficient of Fe$_3$O$_4$ (%)			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018							
0.00	100.00a	100.00a	100.00a	100.00A	0.00h	9.57g	38.34de	15.97D
2000	93.62b	94.15b	89.23c	92.33B	0.00h	40.97cd	54.67b	31.88A
4000	82.03d	81.97d	82.90d	82.30C	0.00h	35.20e	51.77b	28.99B
6000	65.86f	71.37e	68.11f	68.45D	0.00h	34.74e	59.05a	31.27A
8000	45.39h	58.91g	56.33h	53.54E	0.00h	27.70f	42.57c	23.42C
Mean	77.38C	81.28A	79.61B		0.00C	29.64B	49.28A	
	Second season; 2019							
0.00	100.00a	100.00a	100.00a	100.00A	0.00j	27.67i	53.87f	27.85E
2000	92.09b	88.49c	88.10c	89.56B	0.00j	86.41d	102.5c	62.97B
4000	82.04d	81.89d	85.50c	83.14C	0.00j	40.55h	64.07e	34.87D
6000	66.31e	68.89e	66.22e	67.14D	0.00j	48.95g	63.88e	37.61C
8000	0.00h	62.06f	56.33g	39.46E	0.00j	325.0b	452.0a	259.0A
Mean	68.09C	80.27A	79.23B		0.00C	106.1B	147.3A	

Mean followed by the same letter in a column or row don’t differ significantly according to Duncan’s New Multiple Range test

Chemical composition of the leaves

It is evident from data presented in *Table 8* that the gradual increase of salinity level resulted a gradual decrease in concentrations of chlorophyll a, b and carotenoids (mg/g f.w.) and the percentages of N and P except for 2000 ppm salinity level that raised P concentration to 0.752% versus 0.657% for control. The opposite was the right in relation to K, Na and Cl percentages as well free proline (mg/100 g d.w.). Which was progressively increased with increasing salinity level.

Magnetite, on the other side, linearly elevated concentrations of the previous constituents as the rate of its application was increased except for N and Na percentages which were adversely affected. Also, Fe$_3$O$_4$ at 4 g/plant rate diminished Cl %, whereas 2 g/plant rate increased it.

The highest concentrations of chlorophyll a, b, carotenoids and nitrogen were attained by interacting between either zero or 2000 ppm salinity and magnetic iron, especially at 4 g/plant dose, but the highest percent of phosphorus was obtained from 2000 ppm salinity level + magnetite at either 2 or 4 g/plant. The opposite was the right concerning K, Na, Cl and proline, as their maximal concentrations were obtained by combining between 8000 ppm salinity and magnetite at 2 g/plant in most cases of both seasons.

Table 8. *Effect of salinity levels, magnetite rates and their interactions on some constituent's concentrations in Moringa oleifera Lam. leaves during 2019 seasons*

Fe_3O_4 rate (g/plant) / **Salinity level (ppm)**	**Chlorophyll a (mg/g f.w.)**				**Chlorophyll b (mg/g f.w.)**				**Carotenoids (mg/g f.w.)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
	First season; 2018											
0	2.103g	3.384a	3.219c	2.902A	1.640f	1.837d	2.226a	1.901A	0.733a-c	0.810a	0.796ab	0.780A
2000	2.04g	3.319b	3.110d	2.823B	1.631f	1.755e	2.083b	1.823B	0.734a-c	0.817a	0.781ab	0.777A
4000	1.503h	2.233f	2.467e	2.068C	1.36g	1.640f	1.937c	1.651C	0.697c	0.810a	0.790ab	0.766A
6000	1.299i	2.061g	2.201f	1.854D	1.045i	1.321h	1.375g	1.247D	0.675c	0.724bc	0.733-c	0.711B
8000	0.00j	1.293i	1.358i	1.326E	0.00j	1.039i	1.050i	1.045E	0.000e	0.501d	0.540d	0.521C
Mean	1.736B	2.458A	2.471A		1.423C	1.518B	1.734A		0.71B	0.733A	0.728A	
	N (%)				**P (%)**				**K (%)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
0	4.250bc	4.250bc	4.310a	4.270A	0.651cd	0.658c	0.663c	0.657B	1.073l	1.163k	1.177k	1.138E
2000	4.230c	4.240c	4.300ab	4.260A	0.649cd	0.726b	0.880a	0.752A	1.328j	1.396i	1.465h	1.396D
4000	3.760f	3.950e	4.070d	3.930B	0.476g	0.617e	0.635d	0.576C	1.670g	1.793f	1.881e	1.781C
6000	3.350h	3.610g	3.780f	3.580C	0.418hi	0.479g	0.521f	0.473D	1.911d	2.013c	2.094b	2.006B
8000	0.000k	2.360j	2.450i	2.410D	0.00j	0.411i	0.429h	0.420E	0.00m	2.133a	2.148a	2.141A
Mean	3.900C	3.680B	3.782A		0.549C	0.578B	0.626A		1.496C	1.700B	1.753A	
	Na (%)				**Cl (%)**				**Proline (mg/100 g f.w.)**			
	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean	0.00	2 g	4 g	Mean
0	0.859g	0.730j	0.730j	0.773E	1.170g	1.170g	1.100h	1.147E	5.976l	5.910l	5.646m	5.844E
2000	1.013f	0.783i	0.771i	0.856D	0.760e	1.460f	1.430f	1.550D	9.735i	9.315j	9.000k	9.350D
4000	1.079e	0.811h	0.780i	0.890C	2.050d	2.050d	1.790e	1.963C	20.284f	17.391g	17.110h	18.262C
6000	1.303c	1.110d	1.101d	1.171B	2.630a	2.350c	2.310c	2.430B	41.500b	35.581d	31.532e	36.204B
8000	0.000k	1.567a	1.433b	1.500A	0.00i	2.610a	2.500b	2.555A	0.00n	43.610a	38.336c	40.973A
Mean	1.064A	1.000B	0.963C		1.903AB	1.928A	1.826B		19.374C	22.361A	20.325B	

Mean followed by the same letter in a column or row don't differ significantly according to Duncan's New Multiple Range test

Discussion

Effect of soil salinity, magnetite and their interaction on vegetative and root growth parameters

The adverse effects of saline soil on growth may be attributed to either low water uptake due to low potential of soil water (Munns, 2002) or certain ion toxicity (Na^+ and Cl^-) or both (Carter et al., 2005). This fact was emphasized by Elhag and Abdalla (2014) who stated that salinity depresses plant growth via affecting water absorption and biochemical processes such as N, CO_2 assimilation and protein biosynthesis or accumulated high concentration of potentially toxic ions (Na^+ and Cl^-). Jose et al. (2016) ascribed the reduction in growth by salinity to the effect of osmotic stress and the inhibition of cell division rather than cell expansion coupled with the great reduction in photosynthesis. High salinity also leads to leaf abscission due to ion accumulation in the leaves, particularly the oldest ones. Reduction of growth by salinity may be attributed to a decrease in all volume at a constant cell number. Mechanism of salt may result in inhibition of cell division, consequently reduces the rate of plant development (Khan et al., 2009). Jou et al. (2006), however suggested that ATPase participates in the endoplasmic Reticulum-Golgi mediated, protein sorting machinery for both housekeeping function and compartmentalization of excess Na^+ under high salinity. Such truth was aforementioned by Munns (2002) who proposed that salt tolerant plants may have a low rate of Na^+ and Cl^- transport to leaves beside their ability to compartmentalize these ions in vacuoles to prevent their buildup in the cytoplasm or cell walls and thus avoid salt toxicity. The previous results are in accordance with those postulated by Elhag and Abdalla (2014) who found that stem length and No. leaves of 2-months-old moringa transplants were significantly reduced (30 and 40% successively) by the highest NaCl concentration (0.8%). Hence, the 2-months-old moringa transplants can tolerate NaCl concentration up to 0.4%. This tolerance may be attributed to its ability to restrict the transport of toxic Na^+ and Cl^- ions to the shoot at such lower concentration and their accumulation in the older leaves at higher ones to get rid of them by shedding of those older leaves. So, the mechanism of salinity tolerance of moringa may be the avoidance of toxic ions. Likewise, Cassaniti et al. (2013) claimed that brackish water can be commercially used for production of *Chrysanthemum morifolium*, *Dianthus caryophyllus*, *Gerbera jamesonii*, *Hippeastrum vittatum* and *Anthurium andreanum*, up to 2500 ppm. Similarly, were those results of Shahin et al. (2008) on *Ficus macrocarpa* var. Hawaii and *Euonymus Japonica* cv. Mediopicta, Shahin et al. (2013) on *Ficus benjamina* cv. Samanthaand *Schefflera arboricola* cv. Gold Capella, El-Fouly et al. (2015) on *Iris tingitana* cv. Wedgewood, Jose et al. (2016) on *Eucalyptus urophylla* and the hybrid of *E. urophylla* x *E. grandis* Shahin et al. (2017) affirmed that a gradual decrement in vegetative and root growth of both *Casuarina equisetifolia* and *Eucalyptus rostrata* seedlings was observed due to the gradual increment in salinity concentration from 5000 to 15000 ppm.

On the other hand, the positive effect of magnetic iron on growth of plants suffered from salt stress may be due to its role in promoting the uptake of N, P, K and Fe which stimulates plant growth against the toxicity of Na^+ and Cl^- ions that inhibit it. It induces cell metabolism and mitosis of meristematic cells (Barage et al., 2009). It is believed that new protein bands are formed in plants that are treated with Fe_3O_4 and these proteins are responsible for the increased growth (Hozyan and Abdul-Qodos, 2010). Furthermore, it declines the hydration of salt ions and colloids, increasing salt solubility,

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and finally leading to leaching such salts from the soil. In the iron atom, there is a number of valence electrons that generates a magnetic field influence on the biochemical processes in plants and renders the roots to exhibit symptoms of magnetism that kills nematodes and injurious bacteria (Yuliando et al., 2016). The aforementioned gains are in harmony with those obtained by Dos Santos et al. (2011) and Nouman et al. (2012b) on *Moringa oleifera* and Moustafa et al. (2017) who pointed out that seedlings length, No. leaves, root length, No. roots and aerial parts and roots fresh and dry weights of *Moringa oleifera* seedling subjected to salinity up to 8000 ppm were improved in response to applying Fe_3O_4 at 2 g/pot. Supporting results for this study were also obtained by Abdel-Fattah (2014) on *Jacaranda acutifolia*, Ahmed et al. (2016) on *Acalypha wilkesiana*, Shahin et al. (2018) on *Terminalia arjuna* and El-Sayed et al. (2019) on elephant`s ear tree.

Salt resistance index (SRI %) and benefit coefficient of magnetite (B. Coe. %).

These results are reasonable because magnetite usually solubilizes and leaches salts from the soil, and this gives roots a chance to penetrate and distribute well through the growing medium, consequently uptake enough water and nutrients necessary for good and healthy growth. On the same line were those results attained by Al-Qubaie et al. (2003) on *Ficus benghalensis*, *Bougainvillea glabra*, *Jasminum azoricum*, *Conocarpus erectus*, *Tamarix articulata* and *Ziziphus spina-christi*, Shahin et al. (2008) on *Ficus macrocarpa* Var. Hawaii and *Euonymus Japonica* cv. Mediopicta, Abdel-Fattah et al. (2012a) on *Ficus retusa*, Abdel-Fattah et al. (2012b) on *Ficus benjamina* and El-Sayed et al. (2019) on *Enterolobium contortisiliquum*.

Chemical composition of the leaves

The previous data showed the effect of the gradual increase of salinity level may be reasonable because salts usually reduces the water potential of soil solution, consequently decreases minerals and water uptake by roots, accompanied by a depression of photosynthesis and enzymes activity (Munns, 2002). It was also remarkable that accumulation of some amino acids and amides in the leaves and roots of salinity-stressed plants may be attributed to *de novo* synthesis by protein sorting machinery and not the result of protein degradation (Jou et al., 2006).

On the other hand, improving constituent's concentrations by magnetic iron may indicate its role in repairing salinity harms by reducing Na^+ and Cl^- toxic ions in the medium, coupled with increasing the free proline formation which improves as a colloid water balance in plant cells (Mostafazadeh et al., 2012). Further, Fe_3O_4 may create a high energy magnetic field in the root medium which may increase the solubility of N, P, K and Fe nutrients and this in turn promotes the absorption of such minerals, improving ultimately plant growth (Yuliando et al., 2016).

These results, showed a similar trend to those of Elhag and Abdalla (2014) and Moustafa et al. (2017) on *Moringa oleifera*, Ahmed et al. (2016) on *Acalypha wilkesiana*, Shahin et al. (2018) on *Terminalia arjuna* and El-Sayed et al. (2019) who observed that chlorophyll a, b, carotenoids and total carbohydrates concentrations were increased in the leaves of *Enterolobium contortisiliquum* under salt stress by application of Fe_3O_4 at either 2 or 4 g/plant.

Conclusion

From the previous findings, it can be proposed to apply magnetic iron at the rate 4 g/plant for enhancing growth and quality of *Moringa oleifera* seedlings under salt stress up to 6000 ppm.

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