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How far *Tagetes erecta* can tolerate different salinity levels by using magnetic iron?

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ABSTRACT
An experiment was carried out in Hort. Res. Inst., ARC, Giza, Egypt during the 2020 and 2021 seasons under nursery full sun, to investigate the role of magnetic iron (Fe_3O_4) at rates of 0, 2, 3, and 4 g/plant in lowering the harmful effect of saline water ($NaCl + CaCl_2$) at concentrations of 0, 1000, 2000, and 3000 ppm on growth, flowering, and chemical characteristics for marigold plants. Interactions between saline water and Fe_3O_4 treatments were also investigated. The results demonstrated that, with a few exceptions in both seasons, the mean values of vegetative and root development characteristics (plant height, stem diameter, the number of leaves/plant, root length and aerial parts, and root fresh and dry weights) were identical and gradually decreased with increasing salinity, but gradually increased when the rate of Fe_3O_4 was raised. The interaction treatments had a significant impact on the previous growth traits, with varying degrees of significance, but the most significant effect was for combining irrigation with fresh water and drenching the soil mixture with 4 g Fe_3O_4/plant, which produced the highest values in general among all the other combinations in the two seasons. Flowering characteristics (flower diameter, flower fresh and dry weights, and flower number per plant), as well as leaf pigment, N, P, and K content, followed a similar pattern, although Na, Cl, and proline leaf content followed the opposite trend.. Thus, under salty water stress, immersion of the soil mixture with Fe_3O_4 (4g/plant) might be advised to improve the development, blooming, and quality of marigold (*Tagetes erecta* L.) seedlings.

Keywords: Marigold, *Tagetes erecta* L., magnetite, saline water, vegetative and root growth, flowering, chemical composition

1. Introduction

Tagetes species (Marigolds) are one of the most popular annual ornamental plants belonging to the family Asteraceae, which are frequently used as ornamentals and in a variety of fields such as cosmetic preparation and medicine. Flowers come in a variety of hues, ranging from white to yellow to orange or golden red, and are employed in the extraction process for all of these functions.

African or American Marigolds (*Tagetes erecta* L.) are the most common Tagetes types. They are tall, erect-growing plants. The blooms are big and globe-shaped. They make excellent bedding plants. These blooms are golden to orange in colour and have no red in them. It takes longer to reach the flowering stage than the French type. The two other varieties are French Marigolds (*T. patula*) and Signet Marigolds (*T. signata* pumila).

As a cover crop, Tagetes species are utilised. It generates alpha-terthienyl, a chemical that can help to reduce root-knot nematodes and other disease-causing organisms including fungus, bacteria, insects, and viruses. Many workers reported that *Tagetes erecta* is moderately tolerant to salt stress (Sayed, 2014; Chrysargyris *et al.,* 2018; Bezerra *et al.,* 2020).In this regard, Zapryanova and Atanassova (2009) mentioned that suppression in *Tagetes patula* plants were increased with increasing NaCl concentration. Similar observations were also obtained by Sayyed (2014) on *Tagetes erecta,* Chrysargyris *et al.,* (2018) on *Tagetes patula,* and Bezerra *et al.,* (2020) on *Tagetes patula*, *Catharanthus roseus*, and *Celosia argentea*.

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On the other hand, magnetic iron is used now, on a wide scale for mitigating the harmful effects of salinity on various plants. For this concern, Ahmed *et al.,* (2016) recommended drenching the salt-affected soil up to 6000 ppm concentration with 6 g/pot magnetites, four times at a two month interval, to improve the growth performance and quality of *Acalypha wilkesiana* transplants. Similarly, Abdel-Mola and Ayyat (2020) on *Calendula officinalis*, Nofal *et al.,* (2021) on *Moringa oleifera*, Abd El-All and Mohammed (2014) broccoli and cauliflower, Abobatta (2015) onValencia orange, Askary *et al.,* (2017) on Menthapiperita, and Abo-Gabien *et al.,* (2020) on olive.

The goal of this research is to see how magnetite can help marigold plants overcome the negative impacts of saline water on their vegetative development, blooming, and chemical composition.

2. Materials and Methods

This study aims to improve the tolerance of *Tagetes erecta* L seedlings to salinity stress. The polyethylene plastic bags were placed in full sun at the Hort. Res. Inst., ARC, Giza, Egypt, through two consecutive seasons of 2020 and 2021, two month-old seedlings of *Tagetes erecta* L with a length of about 10 cm were transplanted in 20-cm-diameter polyethylene bags filled with sand and clay (1:1, v/v) on January 1st for each season.

Table (a) shows the physic-chemical parameters of the sand and clay utilized in the investigation.

Table (a): The physic-chemical properties of the sand and clay utilized in the study.

Soil type	Particle size distribution (%)				S.P.	E.C. (dS/m)	pH	Cations (meq/L)				Anions (Meq/L)		
	Sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{--}
Sand	84.11	5.57	1.55	8.67	22.46	3.59	7.86	15.69	8.01	7.3	1.74	3.14	16.93	12.67
Clay	7.82	23.26	28.83	36.54	49.05	2.25	8.02	13.93	2.19	15.97	1.6	6.5	17.71	9.48

The experimental treatments were as follows:

2.1. Salinization treatments

Two weeks after planting, irrigation water was salted with a salt combination of pure sodium chloride and calcium chloride salts (1:1 by weight) at concentrations of 0, 1000, 2000, and 3000 ppm (on January 15th). The plants were watered twice a week during the trial.

2.2. The magnetite treatments

Magnetic iron (Fe_3O_4) was added as a soil drench thoroughly at levels 0, 2, 3, and 4 g/ plant (pot). The first pot was added after two weeks from transplanting (on 15th, January) and then once every month.

2.3. Interaction treatments

Each level of salinity was combined with each of the magnetites to make 16 combinations. The plants were fertilized twice during this study with chemical fertilizer (20:20:20 + micronutrients) at 2 g /plant.

Plant height (cm), stem diameter at the base (cm), number of leaves per plant, flower diameter (cm), root length (cm), and fresh and dried weights of aerial parts and roots (g) were recorded at the end of each season (on 15th May). Yadava (1986) method was used to determine the content of photosynthetic pigments (chlorophyll a, b, and carotenoids, mg/g FW) in fresh leaf samples. Nitrogen percentage were evaluated in dry samples by Pregl, (1945), phosphorus (Luatanab and Olsen, 1965), potassium, sodium, and chloride (Jackson, 1973). The content of free proline (mg/g d.w.) was evaluated by Batels *et al.* (1973).

For means comparison, the data was tabulated and statistically analysed using SAS Institute's (2009) software and Duncan's New Multiple Range t-Test (Steel and Torrie, 1980).

3. Results and Discussion

3.1. Effect of salinity, magnetite, and their interactions on:

3.1.1. Vegetative and root growth traits

According to the data presented in Tables 1, 2, 3, and 4, the means of the various vegetative and root growth measured as plant height (cm), stem diameter (cm), the number of leaves/plant, root length (cm), and aerial parts and roots fresh and dry weights (g) lowered happening with elevating salinity levels to reach the lowest values by 3000 ppm salinity level in the two seasons, except for the means of root fresh weight (g) in the first season (g).Low water intake owing to low soil water potential, ion toxicity (Na+ and Cl-), or both may be to blame for causing harmful influences of salinity on growth (Zapryanova and Atanassova, 2009). Furthermore, Jose *et al*., (2016) linked salinity's influence on plant development to osmotic stress and repression of cell division actually than cell expansion, as well as a significant reduction in photosynthesis and protein production. In this regard, Sayyed (2014) found that NaCl salt at a concentration higher than 100 mM significantly decreased plant height, root length, the number of leaves, and fresh and dry biomass for *Tagetes erecta* plants. Likewise, in *Tagetes patula* plants, Chrysargyris *et al.,* (2018) discovered that 100 mMNaCl reduced plant biomass and height, as well as a result; physiological processes such as stomatal closure were negatively affected.

In addition, soaking the soil mixture with a gradual increment of magnetic iron was accompanied by a gradual decrement in salinity hazards on various growth characters. Thus, the tallest and thickest plants with the highest number of leaves, the longest root high and the heaviest aerial parts and roots, both fresh and dry weights, were acquired, for two seasons by applying 4 g Fe_3O_4/plant (pot), regardless of salinity level. This might point to the involvement of magnetic iron in elevating the absorption of the minerals, which help plants develop while protecting them from the toxicity of Na+ and Cl-ions. It causes meristamatic cells to undergo cell metabolism and mitosis (Baraga *et al*., 2009). Furthermore, Fe_3O_4 lowers the hydration of salt ions and colloids, increasing salt solubility and, eventually, promoting salt leakage from the soil, according to Mostafazadeh *et al*. (2012). The iron atom has a number of valence electrons that generate a magnetic field that regulates biochemical processes in plants and causes magnetic symptoms in the roots that kill worms and hazardous bacteria, according to Yuliando *et al.,* (2016). However, these findings are consistent with those found by Ahmed *et al.,* (2016) on *Acalypha wilkesiana*, Abdel Mola and Ayyat (2020) on *Calendula officinalis,* and Nofal *et al.,* (2021), who mentioned that drenching soil mixture with Fe_3O_4 at a level 4 g/pot enhanced Moringaoleifera seedlings' development and quality during salt stress up to 8000 ppm concentration.

Interaction treatments showed a marked effect on the different vegetative and root growth traits cited before, with varying significance among them. The advantage, however, was for combination plants in a soil mixture supplied with fresh water and receiving magnetite at 4 g/pot rates, as this combined treatment gave, in general, the highest records in most growth traits in comparison to all other seasons' combinations. This may be understandable because Fe_3O_4 is a key nutrient involved in the production of chlorophyll, DNA, chloroplast formation, respiration, and many other metabolic pathways, and it is irrigated with freshwater devoid of toxic ions (Soleiman *et al.,* 2021). According to Abdel-Mola and Ayyat (2020), foliar application of chitosan at 200 and 400 ppm concentrations considerably reduced the symptoms of acne the deleterious effects saline water up to 5000 ppm on the vegetative and root growth criteria of potted *Calendula officinalis* plants. Similarly, Ahmed *et al.,* (2016) on a copper-leaf plant, Abobatta (2015) on Valencia orange trees, and Askary *et al.,* (2017) declared that a suitable concentration of Fe_2O_3NPs (30 uM) could be used for peppermint salt stress resistance (150 mMNaCl). Likewise, Abo-Gabien *et al.,* (2020) observed that combining magnetic iron at 750 g/olive tree and K-humate at 75 g/trees improved growth and fruiting aspects under salt stress in the south Sinai.

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Table 1: Effect of water salinity, magnetite, and their interactions on plant height and stem diameter of *Tagetes erecta* L. plant during the 2020 and 2021 seasons.

Salinity (ppm) / Magnetite	Plant height (cm)					Stem diameter (cm)				
	Control	1000	2000	3000	Mean	Control	1000	2000	3000	Mean
First season; 2020										
Control	35.73de	33.97g	30.07i	24.10k	30.97D	0.677cd	0.603ef	0.580ef	0.550f	0.603C
2 g/pot	37.60c	34.27fg	30.77i	25.03k	31.92C	0.727c	0.640de	0.580ef	0.560f	0.627C
3 g/pot	40.37b	35.03ef	32.03h	27.13j	33.64B	0.827b	0.687cd	0.600ef	0.590ef	0.676B
4 g/pot	45.67a	36.33d	34.07fg	29.87i	36.48A	0.963a	0.733c	0.610ef	0.610ef	0.729A
Mean	39.84A	34.90B	31.73C	26.53D		0.798A	0.666B	0.593C	0.578C	
Second season; 2021										
Control	36.81de	34.99g	30.97i	24.82k	31.90D	0.741d	0.661ef	0.600gh	0.560h	0.640D
2 g/pot	38.73c	35.29fg	31.69i	25.78k	32.87C	0.796c	0.701de	0.603f-h	0.580gh	0.670C
3 g/pot	41.58b	36.08ef	32.99h	27.95j	34.65B	0.905b	0.752cd	0.620fg	0.610f-h	0.722B
4 g/pot	47.04a	37.42d	35.09fg	30.76i	37.58A	1.055a	0.803c	0.630fg	0.620fg	0.777A
Mean	41.04A	35.95B	32.69C	27.33D		0.874A	0.729B	0.613C	0.593C	

Means in a column or row followed by the same letter do not differ significantly, according to Duncan's New Multiple Range t-Test at the 5% level.

Table 2: Effect of water salinity, magnetite, and their interactions on the number of leaves/plant and root length of *Tagetes erecta* L plant during 2020 and 2021 seasons,

Salinity (ppm) / Magnetite	Number of leaves/plant					Root length (cm)				
	Control	1000	2000	3000	Mean	Control	1000	2000	3000	Mean
First season; 2020										
Control	98.00c-e	91.33f	79.33h	66.00i	83.67D	20.73fg	20.97fg	20.00h	19.10i	20.20D
2 g/pot	102.33c	94.00ef	84.00g	68.00i	87.08C	22.77d	23.77c	20.50gh	20.47gh	21.88C
3 g/pot	109.67b	96.33de	86.67g	68.67i	90.33B	24.20bc	24.50b	21.00fg	21.03fg	22.68B
4 g/pot	124.67a	100.33cd	91.33f	75.33h	97.92A	28.30a	24.83b	21.90e	21.37ef	24.10A
Mean	108.67A	95.50B	85.33C	69.50D		24.00A	23.52B	20.85C	20.49D	
Second season; 2021										
Control	99.47de	92.70g	80.52j	66.99m	84.92D	22.05ij	22.29h-j	23.70fg	20.42k	22.12D
2 g/pot	103.87c	95.41f	85.26i	69.02lm	88.39C	24.09f	25.09e	23.21g	21.79j	23.55C
3 g/pot	111.31b	97.78ef	87.97h	69.70l	91.69B	25.52de	25.82cd	25.33de	22.35hi	24.76B
4 g/pot	126.50a	101.80cd	92.70g	76.46k	99.39A	29.62a	26.15bc	26.38b	22.69h	26.21A
Mean	110.30A	96.93B	86.61C	70.54D		25.32A	24.84B	24.66B	21.81C	

Means in a column or row followed by the same letter do not differ significantly, according to Duncan's New Multiple Range t-Test at the 5% level.

Table 3: Effect of water salinity, magnetite, and their interactions on fresh weight of aerial parts and roots of *Tagetes erecta* L. plant during 2020 and 2021 seasons.

Salinity (ppm) / Magnetite	Aerial parts FW (g)					Roots FW (g)				
	Control	1000	2000	3000	Mean	Control	1000	2000	3000	Mean
					First season; 2020					
Control	19.07e	15.10g	12.50j	11.13k	14.45D	6.18e	6.20e	6.00g	5.14i	5.88D
2 g/pot	21.23d	16.80f	14.30h	12.77j	16.27C	7.07d	7.39c	6.08f	5.21i	6.44C
3 g/pot	24.10b	18.60e	16.67f	13.43i	18.20B	7.43b	7.47b	6.14ef	5.46h	6.64B
4 g/pot	29.10a	22.03c	18.57e	14.50h	21.05A	8.18a	7.50b	6.17e	5.49h	6.83A
Mean	23.38A	18.13B	15.51C	12.96D		7.22A	7.14B	6.10C	5.33D	
					Second season; 2021					
Control	20.12e	15.93g	13.19j	11.75k	15.24D	6.72h	6.75h	7.91f	5.60k	6.74D
2 g/pot	22.40d	17.72f	15.09h	13.47j	17.17C	7.69g	8.04e	8.01e	5.66j	7.35C
3 g/pot	25.43b	19.62e	17.58f	14.17i	19.20B	8.13d	8.13d	8.27c	5.94i	7.62B
4 g/pot	30.70a	23.25c	19.59e	15.30h	22.21A	8.90a	8.16d	8.35b	5.97i	7.85A
Mean	24.66A	19.13B	16.36C	13.67D		7.86B	7.77C	8.14A	5.79D	

Means in a column or row followed by the same letter do not differ significantly, according to Duncan's New Multiple Range t-Test at the 5% level.

Table 4: Effect of water salinity, magnetite, and their interactions on aerial parts and roots dry weight of *Tagetes erecta* L. plant during 2020 and 2021 seasons.

Salinity (ppm) / Magnetite	Aerial parts DW (g)					Roots DW (g)				
	Control	1000	2000	3000	Mean	Control	1000	2000	3000	Mean
					First season; 2020					
Control	8.27e	6.69j	5.55n	4.86o	6.34D	2.70e	2.70e	2.40h	2.38h	2.55D
2 g/pot	9.21d	7.32h	6.21l	5.57n	7.08C	3.26d	3.77b	2.51g	2.42h	2.99C
3 g/pot	10.47b	8.08f	7.12i	5.97m	7.91B	3.69c	3.92a	2.58f	2.50g	3.17B
4 g/pot	12.26a	9.47c	7.94g	6.53k	9.05A	3.81b	3.98a	2.65e	2.58f	3.25A
Mean	10.06A	7.89B	6.71C	5.73D		3.37B	3.59A	2.54C	2.47D	
					Second season; 2021					
Control	8.75e	7.08j	5.88n	5.14o	6.71D	2.93h	2.94h	3.70g	2.41j	3.00D
2 g/pot	9.74d	7.74h	6.57l	5.90n	7.49C	3.55g	4.10ef	4.46c	2.48ij	3.65C
3 g/pot	11.08b	8.55f	7.54i	6.31m	8.37B	4.01f	4.26de	5.18b	2.63i	4.02B
4 g/pot	12.97a	10.02c	8.40g	6.91k	9.58A	4.14d-f	4.32cd	5.46a	2.61i	4.14A
Mean	10.64A	8.35B	7.10C	6.06D		3.66C	3.91B	4.70A	2.54D	

Means in a column or row followed by the same letter do not differ significantly, according to Duncan's New Multiple Range t-Test at the 5% level.

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3.2.2. Flowering traits

Tables 5 and 6 shows an averaged similar pattern in terms of vegetative and root growth measures blooming traits, as mean values of flower diameter (cm) and flower, fresh and dry weight (g) in response to the progressive increase in salt level, which were steadily lowered to be the minimum by 3000 ppm salt concentration, but were linearly elevated with elevating Fe_3O_4 to maximum using 4 g/plant dose than control means in both of seasons. Therefore, interacting between irrigation with fresh water and applying the high rate of magnetite (4 g/plant) recorded the largest flower diameter with relation to all other interactions for two seasons (Table, 5).

An identical response occurred as well concerning the number of flowers/plants produced at the 3 different times of flowering period (from 15/2 to 15/3, from 15/3 to 15/4, and from 15/4 to 15/5) for every season (Table, 6). However, the number of flowers produced by plants during the first month of the flowering period (15/2 to 15/3) was slightly higher than that attained in the second month (15/3 to 15/4), especially by plants irrigated with fresh water, but the least amount of flower production was recorded in the third month (15/4 to 15/5) for both seasons, especially by plants watered with 3000 ppm salt concentration.

These results could be supported by those affirmed by Zapryanova and Atanassova (2009), who discovered that *T. patula* plants treated with NaCl (2.0%) bloom faster, have a shorter flowering time, and produce more flowers than untreated plants. Higher saline levels (4000 and 5000 ppm NaCl) produced substantial declines in all blooming characteristics of pot marigold plants, whereas foliar application of chitosan at 200 and 400 ppm concentrations mitigated these adverse effects according to Abdel Mola and Ayyat (2020). On Aggizi olive cv. (*Olea europaea*), Abo-Gabien *et al.,* (2020) indicated that magnetic iron (750 g/tree) and K-humate (75 g/tree) raised the tolerance of olive trees to salinity stress and gave the highest means of flowering measurements relative to untreated trees.

Table 5: Effect of water salinity, magnetite, and their interactions on flower diameter and its fresh and dry weights of *Tagetes erecta* L. Plant during 2020 and 2021 seasons.

Salinity (ppm)	Flower diameter (cm)					Flower FW (g)					Flower DW (g)				
Magnetite	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**
								First season; 2020							
Control	5.80d	5.43ef	4.87h	4.00j	5.03D	3.54d	3.01g	2.95gh	2.79j	3.07D	1.12f	1.01ij	1.00ij	0.96k	1.02D
2 g/pot	6.00d	5.77de	5.07gh	3.97j	5.20C	3.60d	3.43e	2.99g	2.84ij	3.22C	1.18d	1.08g	1.04h	1.00j	1.07C
3 g/pot	7.03b	5.97d	5.33fg	4.20ij	5.63B	5.04b	3.58d	3.08f	2.91hi	3.65B	1.63b	1.14e	1.10g	1.02i	1.22B
4 g/pot	7.73a	6.47c	5.73de	4.47i	6.10A	6.68a	4.09c	3.14f	2.91hi	4.21A	1.98a	1.31c	1.17d	1.01ij	1.37A
Mean	6.64A	5.91B	5.25C	4.16D		4.72A	3.53B	3.04C	2.86D		1.48A	1.14B	1.08C	1.00D	
								Second season; 2021							
Control	6.29d	5.90ef	5.28h	4.34j	5.45D	3.79d	3.26gh	3.20hi	3.04k	3.32D	1.24e	1.12hi	1.11hi	1.06j	1.13D
2 g/pot	6.51d	6.26de	5.50gh	4.30j	5.64C	3.85d	3.68e	3.24h	3.09jk	3.47C	1.30d	1.20f	1.15g	1.10i	1.19C
3 g/pot	7.63b	6.47d	5.79fg	4.56ij	6.11B	5.29b	3.83d	3.33fg	3.16ij	3.90B	1.80b	1.26e	1.21f	1.12gh	1.35B
4 g/pot	8.39a	7.02c	6.22de	4.85i	6.62A	6.93a	4.34c	3.39f	3.16ij	4.46A	2.18a	1.45c	1.29d	1.11hi	1.51A
Mean	7.21A	6.41B	5.70C	4.51D		4.97A	3.78B	3.29C	3.11D		1.63A	1.26B	1.19C	1.10D	

Means in a column or row followed by the same letter do not differ significantly, according to Duncan's New Multiple Range t-Test at the 5% level.

Table 6: Effect of water salinity, magnetite and their interactions on mean number of flowers/plant of *Tagetes erecta* L. during the different times of 2020 and 2021 seasons.

Salinity (ppm)	No. flowers/plant from 15/2 to 15/3.					No. flowers/plant from 15/3 to 15/4.					No. flowers/plant from 15/4 to 15/5.				
Magnetite	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**
								First season; 2020							
Control	9.67d	8.67e	4.56ij	4.11j	6.75D	8.66e	7.7g	4.77k	3.44m	6.16D	8.22d	7.22h	4.11m	2.56o	5.53D
2 g/pot	10.89c	9.11de	6.67g	5.00hi	7.92C	9.77c	8.12f	5.79i	4.22l	6.98C	9.33c	7.33g	5.00l	3.79n	6.36C
3 g/pot	11.78b	9.69d	7.86f	5.56h	8.72B	11.55b	8.56e	6.88h	4.68k	7.67B	10.26b	7.78f	6.00j	4.11m	7.04B
4 g/pot	13.89a	10.56c	9.24de	6.78g	10.12A	12.60a	9.25d	7.66g	5.66j	8.79A	12.33a	8.00e	6.78i	5.33k	8.11A
Mean	11.56A	9.51B	7.08C	5.36D		10.40A	8.43B	6.28C	4.50D		10.03A	7.58B	5.47C	3.95D	
								Second season; 2021							
Control	10.18d	9.13e	4.80ij	4.32j	7.11D	9.13e	8.19g	5.03j	3.63l	6.49D	8.67d	7.61h	4.33e	2.70o	5.83D
2 g/pot	11.47c	9.59de	7.02g	5.27hi	8.34C	10.30c	8.56f	6.10i	4.45k	7.35C	9.83c	7.73g	5.27l	3.99n	6.71C
3 g/pot	12.40b	10.20d	8.28f	5.85h	9.19B	11.12b	9.02e	7.25h	4.93j	8.08B	10.81b	8.20f	6.32j	4.33m	7.42B
4 g/pot	14.63a	11.12c	9.73de	7.14g	10.65A	13.28a	9.75d	8.07g	5.97i	9.27A	13.00a	8.43e	7.15i	5.62k	8.55A
Mean	12.17A	10.01B	7.46C	5.65D		10.96A	8.88B	6.61C	4.74D		10.58A	7.99B	5.77C	4.16D	

Means in a column or row followed by the same letter do not differ significantly, according to Duncan's New Multiple Range t-Test at the 5% level.

3.2.3. Chemical characteristics of the leaves

The findings in Table (7) show that the pigments concentrations (chlorophyll a, b, and carotenoids mg/g f. w.) are all high progressively increased as the level of magnetite was elevated while the salinity concentration was gradually increased and was accompanied by a descending decrement in concentrations of such pigments. Accordingly, the highest pigment concentrations chlorophyll a, b, and carotenoids (mg/g f. w.) were acquired by the highest rate of magnetite, whereas the lowest concentrations of them were found due to irrigation with the highest level of saline water. In general, using Fe_3O_4 alleviated the negative effects of saline water regardless of concentration, but using it in combination with fresh water increased the concentrations of these three pigments to extreme levels.

Similarly, were those results of nitrogen, phosphorus, and potassium as percentages (Table, 8), but the opposite was true in the matter of sodium (%), chloride (mg/g DW), and proline (mg/g DW.) concentrations (Table, 9), as their concentrations were gradually decreased as a result of increasing magnetic iron dose, but were linearly increased with increasing salinity of irrigation water. Therefore, the highest records of Na, Cl, and proline were attained by interacting between the high level of salinity and the absence of magnetite (zero Fe_3O_4).

These results could be discussed similarly to the vegetative and root growth parameters, and they could be supported by findings reported by Sayyed (2014), who discovered that when NaCl concentrations were increased, chlorophyll a, b, and carotenoids concentrations in *Tagetes erecta* leaves decreased dramatically (150 and 200 mM). Furthermore, Chrysargyris *et al.,* (2018) pointed out that chlorophylls content decreased in the leaves of *T. patula* by saline water of 100 mMNaCl, whereas short-term saline exposure activated metabolic processes and some minerals were accumulated in flowers.

Ahmed *et al*. (2016) on *Acalypha wilkesiana*, Abdel-Mola, and Ayyat (2020) on marigold, *Calendula officinalis*, Nofal *et al.,* (2021) on *Moringa oleifera*, Abd El-All, and Mohammed (2014) on broccoli and cauliflower, and Abobatta (2015) on Valencia orange (*Citrus sinensis),* had similar observations, and Askary *et al.,* (2017) who concluded that Fe_2O_3 NPs improved concentrations of P, K, Fe, Zn, and Ca in peppermint leaves under salinity stress of 150 mMNaCl. Lipid peroxidation and proline content under salinity stress were significantly decreased by applying Fe_2O_3 NPs (30 mM). In this regard, Mostafazadeh *et al.,* (2012) reported that magnetised water reduced mean soil cations (Ca^{++}, Na^{+}, and Mg^{++}) and anions (HCO_3-Cl- and SO_4-) at soil depths of 0-20, 20-40, and 40-60 cm.

From the above results, it could be recommended to apply magnetic iron to potted marigold (*Tagetes erecta* L.) plant at a rate of 4 g/pot (plant) when irrigated with saline water (up to 3000 ppm) to alleviate salt stress on the growth, flowering, and quality of such ornamental plants.

Table 7: Effect of water salinity, magnetite, and their interactions on pigments concentration in *Tagetes erecta* L leaves during 2021 season.

Salinity (ppm) / Magnetite	Chlorophyll a (mg/g FW)					Chlorophyll b (mg/g FW)					Carotenoids (mg/g FW)				
	Control	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**
Control	0.624	0.611	0.588	0.545	0.592	0.493	0.450	0.436	0.319	0.425	0.236	0.180	0.178	0.177	0.193
2 g/pot	0.729	0.629	0.603	0.561	0.631	0.495	0.468	0.439	0.358	0.440	0.238	0.220	0.180	0.180	0.205
3 g/pot	0.812	0.644	0.616	0.572	0.661	0.514	0.481	0.450	0.374	0.455	0.253	0.247	0.183	0.181	0.216
4 g/pot	0.838	0.681	0.628	0.587	0.684	0.547	0.500	0.473	0.395	0.479	0.270	0.263	0.197	0.195	0.231
Mean	0.751	0.641	0.609	0.566		0.512	0.475	0.450	0.362		0.249	0.230	0.185	0.185	

Table 8: Effect of water salinity, magnetite, and their interactions on nitrogen, phosphorus and potassium concentrations in *Tagetes erecta* L. leaves during 2021 season.

Salinity (ppm) / Magnetite	N (%)					P (%)					K (%)				
	Control	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**
Control	1.54	1.50	1.21	1.10	1.34	0.25	0.22	0.20	0.15	0.21	1.83	1.63	1.48	1.35	1.57
2 g/pot	1.76	1.55	1.39	1.33	1.51	0.39	0.30	0.24	0.19	0.28	2.15	1.81	1.68	1.65	1.82
3 g/pot	1.95	1.64	1.51	1.45	1.64	0.44	0.42	0.31	0.24	0.35	2.22	1.93	1.84	1.80	1.95
4 g/pot	2.21	1.99	1.76	1.71	1.92	0.74	0.49	0.42	0.30	0.49	2.39	2.09	1.95	1.91	2.09
Mean	1.87	1.67	1.47	1.45		0.46	0.36	0.29	0.22		2.15	1.87	1.74	1.76	

Table 9: Effect of water salinity, magnetite, and their interactions on Na (%); Cl and proline concentrations in *Tagetes erecta* L. leaves during 2021 season.

Salinity (ppm) / Magnetite	Na (%)					CL (mg/g DW)					Proline (mg/g DW)				
	Control	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**	**Control**	**1000**	**2000**	**3000**	**Mean**
Control	2.48	2.64	2.71	2.77	2.65	1.12	1.46	1.82	2.03	1.61	0.87	1.14	1.77	1.98	1.44
2 g/pot	2.41	2.58	2.64	2.68	2.58	1.09	1.32	1.76	1.88	1.51	0.84	1.04	1.65	1.86	1.35
3 g/pot	1.90	2.54	2.60	2.60	2.41	1.04	1.26	1.64	1.68	1.41	0.82	0.98	1.57	1.75	1.28
4 g/pot	1.49	2.48	2.58	2.56	2.28	0.99	1.18	1.40	1.53	1.28	0.79	0.90	1.50	1.63	1.21
Mean	2.07	2.56	2.63	2.65		1.06	1.31	1.66	1.78		0.83	1.02	1.62	1.81	

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