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Influence of Soil Type, Sowing Date and Diluted Seawater Irrigation on Seed Germination, Vegetation and Chemical Constituents of *Moringa oleifera*, Lam.

M. A. Hegazi[1]

[1] Department of Horticulture (Floriculture), Faculty of Agriculture, Kafr El-Sheikh University, Kafr El-Sheikh, Egypt

Correspondence: M. A. Hegazi, Department of Horticulture (Floriculture), Faculty of Agriculture, Kafr El-Sheikh University, Kafr El-Sheikh, Egypt. Tel: 20-106-603-3059. E-mail: abohegazi@yahoo.com

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Abstract

Two pot trials were conducted during the period of February 15 – October 15 of 2012 and 2013 seasons at two different locations, to evaluate the effect of soil type, sowing date and diluted seawater irrigation on: germination percentage in the first trial and on both plant vegetation and leaves chemical constituents of moringa (*Moringa oleifera*, Lam.) in the second one. The results showed that, generally, Kafr El-Sheikh area (Agricultural area where clayey soil and Nile River water is available) outperformed Balteem area (coastal area where soil is silty clay and seawater is available) in most studied characters. Lowest seawater ratios in *Moringa oleifera* irrigation water gave the best results for germination %, growth characters and some chemical and mineral contents as total green color, leaf protein, total carbohydrates, nitrogen, potassium, calcium and magnessium whereas, the highest ratios gave the best results for phosphorus and sodium contents.

Keywords: Moringa (*Moringa oleifera*), soil type, sowing date, diluted seawater

1. Introduction

Moringa (*Moringa olifera*, Lam.) belongs to family Moringaceae. It is a fast growing, drought tolerant able to tolerate poor soil (Joly, 1979). Moringa tree is drought and salt tolerant and low nutrients requirements (Fuglie, 1999). It produces a tuberous taproot which helps explain its observed tolerance to drought conditions (Ramachanran & Gopalakrishnan, 1980). It is cultivated for multiple purposes because all its parts including seeds, stems, shoots, leaves, flowers, fruits and roots are useful and many farmers are taking interest to cultivate it as field crop for fodder and vegetable production (Amaglo, 2007; El-Dabh et al., 2011). The tree is particularly renowned for its great versatility, as its uses include being a food source for humans and animals alike, coagulant for water purification, remedy for numerous ailments as well as a source for biofuel production (Anwar et al., 2007; Peixoto et al., 2011; Pontual et al., 2012). *Morirga alifera*, Lam seeds have an oil content of between 35-40% which was recently analyzed and found suitable for the production of biofuel in the form of biodiesel (Rashed et al., 2008).

One of the most urgent global problems especially in Egypt after the latest developments in the upstream of the River Nile is the lack of irrigation water. Since Egypt, overlooking both Mediterranean and Red Sea, where they could be used as a renewable source of irrigation water by choosing the salt-tolerant plant species as moringa. Nearly every country in the world experiences water shortages during certain periods of the year (Gleick, 1993), and more than 80 countries now suffer from serious water shortages (Jin et al., 2007). Agricultural production consumes more freshwater than any other human activity. To cope with the scarcity of freshwater for the sustainable development of agriculture, there is increasing awareness among agricultural scientists and planners in the utilization of seawater (at least diluted) for irrigation of crops (Fang & Chen, 1997; Jin et al., 1999; Liu et al., 2003).

The aim of this research was to study how to expanding in moringa (*Morirga alifera*, Lam.) tree afforestation at the edges of roads and waterways in all villages and towns of the province of Kafr El-Sheikh, Egypt, and the possibility of using diluted seawater to irrigate these trees especially in the coastal areas, for its benefits not only in human and animal feed, but also the many medical uses, in addition to providing the Nile water to irrigate basic crops such as wheat and cotton.

2. Materials and Methods

Two pot trials were conducted during 2012 and 2013 seasons at two different locations of Kafr El-Sheikh Governorate to evaluate the effect of soil type, sowing date and diluted seawater irrigation on moringa (*Moringa oleifera*, Lam.) as follow:

a - Effect on seed germination percentage.

b - Effect on plant vegetation and leaves chemical constituents.

Two different represented areas in both irrigation water source and soil type were carefully selected, the first was Balteem (coastal area) where, seawater and silty clay soil are available. The second one was the city of Kafr El-Sheikh (Agricultural area), where is featuring with freshwater (Demietta branch of Nile River) and clayey soil as the treatments have been conducted under both selected areas.

2.1 Plant Material and Procedure

i. First trial: Moringa seeds were collected from a certain mother shrubs grown in some private nurseries during the summer and Autumn months of the above year, sown in plastic tea cups 250 ml filled with the same area soil which the experiment carried out at every sowing date, as one seed in each cup and placed into 75% network home, where the germination experiment took only four weeks before transplanting in 30cm diameter pots. Samples of the two Experimental areas soils were taken and preserved for analysis. The physical and chemical characteristic of experimental soils were provided (Table 1).

Table 1. Physical and chemical analysis of the used soil (Mean of both seasons)

Soil area	Sand	Silt (%)	Clay	Soil texture	EC (mmhos/cm)	pH	Total N (ppm)	Total P (ppm)	OM (%)
Kafrelsheikh	8.13	41.33	48.57	Clayey	0.45	738	55	28	1.61
Balteem	14.17	60.01	25.63	Silty clay	0.90	7.85	23	11	045
	Soluble cations (meq/l)				Soluble anions (meq/l)				
	Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl^-	SO_4^{2-}	
Kafrelsheikh	1.05	0.08	2.00	1.00	-	2.81	0.81	0.51	
Balteem	5.60	0.18	3.64	3.30	-	20.04	29.00	5.62	

The abovementioned plastic tea cups were equally divided into six groups as every group contain 30 cups considered as a treatment (three replicate) and irrigated twice a weekly with suitable diluted seawater. The treatments were freshwater (0% seawater) beside five diluted seawater percentages (10, 15, 20, 25 and 50 % seawater). Seawater was diluted with freshwater to the required levels (0, 10, 15, 20, 25 and 50% seawater) in a plastic tank. Some chemical properties of used seawater (collected from the sea in Balteem beach) and freshwater were shown in Table 2.

Table 2. Chemical analysis of seawater and tap water (Mean of both seasons)

Sample	pH	EC (dSm^{-1})	Na^+ (ppm)	Cl^-	CO_3^{2-}(Meq/l)	Ca^{2+}	Mg^{2+}	N (%)	P (ppm)	K (ppm)
Seawater	8.11	52.63	11523	589.4	1.6	28	182	1.5	115.62	253
Freshwater	7.38	3.5	325.9	1.3	0.8	16.4	7.7	0.4	0.3	5.1

ii. Second trial: Four weeks after the second sowing date (March 15th), the uniform seedlings of each diluted seawater level were transplanted into pots (one plant/30 cm diameter plastic pots filled with 8–10 kg of the same experimental area soil) and remained in open atmosphere. The experiment was conducted in February 15 – October 15 of 2012 and 2013 seasons in completely randomized design according to Snedecor and Cochran (1980) with three replications as every replicate contains five pots. Each pot received 500 ml/pot twice a weekly of the same abovementioned diluted seawater concentrations throughout the course of the study. All plants received the recommended constant stand dose of NPK at the ratio of 1:1:1 at the rate of 5 g/pot. The application started two months after seed sowing and repeated every month till the termination of the experiment. The fertilizers applied for research plots were ammonium sulphate "20% N", calcium super phosphate "15.5% $P_2 O_5$" and potassium sulphate "48% K_2O".

2.2 Measurements

Before start of the experiment both seawater and soil samples were transferred to the center laboratory of Kafr Elsheikh University for analyzing chemical constituents, electrical conductivity (EC) and pH. Two weeks after each monthly seeds sowing date, number of germinated seeds counted every three days till germination stop (during the period of February 15 – October 15 of each season) according to the rules of the Association of Official Seed Analysts (AOSA 1990). Seed germination percentage was calculated using the following equation:

$$G\% = \frac{No.of.germimated.seeds}{Total.seed.number} \times 100 \quad (1)$$

At the end of the experiment (last week of November of each season), the growth criteria were measured (plant height, stem diameter, aerial parts fresh and dry weights, compound leaves number and area/ plant (the fourth leaf from five plants tip of each replicate were taken to leaf area determination using LI-3100C Area Meter), leaves fresh and dry weights/plant, roots number, roots fresh and dry weights/plant). Chemical constituents of leaves were determined at the harvest time as leaf total green color was measured using a portable chlorophyll meter (Minolta SPAD-502, Japan), total soluble protein was measured according to Bradford (1976) and total carbohydrates was determined by the calometric method (AOAC, 1990). Minerals contents (N, P, K, Na, Ca, Mg) were determined in samples of leaves dry powder as described by Cottenie et al. (1982).

2.3 Statistical Analysis

The experiments were conducted twice and the obtained data were subjected to statistical analysis of variance (ANOVA). ANOVA were computed using MSTAT-C (MSTAT Development Team 1989) and the mean separations were carried out according to Duncan's multiple range tests (Duncan, 1955) and significance was determined at $p < 0.05$ using MSTAT-C software.

3. Results and Discussion

3.1 Effect of Soil Type, Sowing Date and Diluted Seawater Irrigation on Moringa oleifera, Lam., Seed Germination Percentage

Germination percentage was taken as the only indicator for the success in moringa seed germination at the selected areas. Silty clay soil (Balteem area) surpassed clay soil (Kafr El-Sheikh area) in germination percentage in most sowing dates. As for sowing date, it was noted from Figure 1 that, germination percentage was very weak in the first schedule of the experiment (February, March and April) and then started to rise gradually with reasonable rates beginning from may even reach the highest germination percentages during June, July and August months and then taken to decline gradually until reaching very low at the end of the experiment (November).

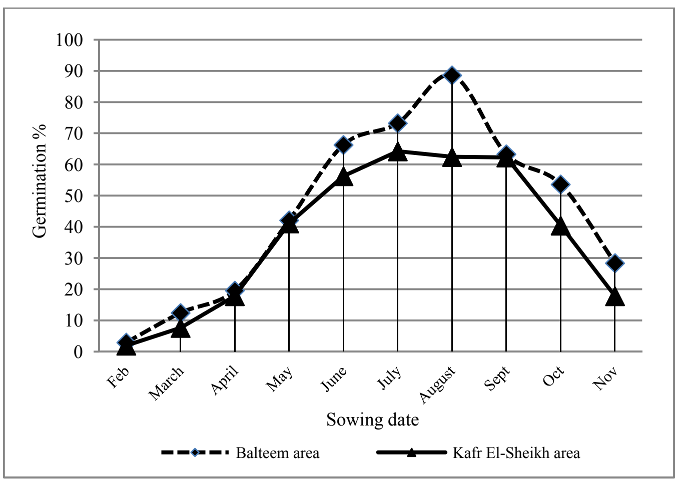

Figure 1. Effect of sowing date on *Moringa oleifera*, Lam., seed germination percentage

A low seawater ratios (10 and 15%) gave germination percentage convergence with that obtained from freshwater in both studied areas (Figure 2). Germination percentage considerably decreased with the increase in seawater proportion (25%) even almost nonexistent when the ratio became 50% seawater. Salinity stress may affects seed germination either through osmotic effects, by preventing or delaying germination (Welbaum et al., 1990), or through ion toxicity, which can render the seeds unviable (Huang & Reddman, 1995). Mauromicale and Licandro (2002) found that salinity increase results in decrease in germinability and delayed rate of germination of globe artichoke. Higher germination percentage (60%) of *Halianthus annuus* seeds was observed when sandy media was used. However, low germination percentage (40%) was observed in the clay treatments (Ogboghodo & Omonhinmin, 2003).

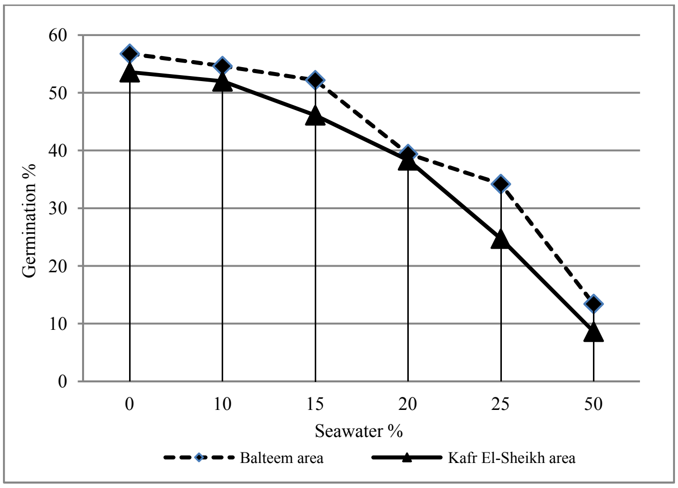

Figure 2. Effect of diluted seawater irrigation on *Moringa oleifera*, Lam., seed germination percentage

3.2 Effect of Soil Type and Diluted Seawater Irrigation on Growth Characters and Some Chemical Constituents of Moringa oleifera, Lam.

3.2.1 Effect on Growth Characters

i. Soil type: It was noticed that, *Moringa oleifera*, Lam., plants planted at Kafr El-Sheikh area were characterized with strong growth in general compared to that planted at Balteem area (Tables 3, 4 and 5). Kafr El-Sheikh area results were supreme for all growth characters except plant height, stem diameter and root fresh and dry weights. Superiority that appears in the results of Kafr El-Sheikh area plants is probably due to that, Kafr El-Shaikh area soil is clay whish features with not only high levels of both organic matter and mineral elements, but also, high capacity to retain water, compared to silty clay soil in Balteem area which is poor in many of these qualities. Gradually decrease in all studied growth characters may be due to that, highest percentage of seawater increased soil salinity which led to moringa plants deterioration. Soil salinity affects the plant growth by several physiological and biochemical means like ion toxicity, osmotic stress, nutritional imbalance and biochemical and negatively correlated with Na concentration. This nutritional imbalance resulted in the reduction of number of leaves and branches and stunted shoot growth in melon (Sivritepe et al., 2003). This is consistent with Innocent Pahla et al. (2013) who reported that, total plant dry matter increase as the clay content of the soil increased in the soil. They obtained 45 and 72.3 g of *M. oleifera* total dry matter when they used sandy and clay soil respectively. Soil texture is important factor where clays generally compromise the majority of cation exchange sites in soils. This is because clays by virtue of their small particle size have the most surface area and therefore the most exchange sites. Consequently, clay soils have the greatest risk for excess sodium binding and dispersion (Leal et al., 2009).

Table 3. Effect of soil type and diluted seawater irrigation on plant height, stem diameter and aerial parts fresh weight of *Moringa oleifera*, Lam. (Mean of both seasons)

Seawater %	Plant height (cm)			Stem diameter (cm)			Fresh aerial parts (g)		
	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean
0	161.30d	175.0b	168.2b	1.94b	1.88c	1.91b	170.50b	140.05g	155.31b
10	168.43c	177.15a	172.80a	2.05a	1.80d	1.93a	174.38a	146.13d	160.32a
15	156.53g	160.88e	158.70c	1.80d	1.76e	1.78c	148.08c	141.88f	145.01c
20	156.07h	158.69f	157.4d	1.74f	1.66g	1.70d	145.67e	127.68i	136.70d
25	137.44i	131.77j	134.6e	1.46i	1.54h	1.50e	129.53h	93.56j	111.50e
50	94.39l	105.52k	99.96f	1.18k	1.27j	1.23f	89.62k	88.91l	89.27f
Mean	145.7b	151.5a		1.70a	1.70a		143.00a	123.00b	

Note. Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

Table 4. Effect of soil type and diluted seawater irrigation on aerial parts dry weight, leaf number and leaf area of *Moringa oleifera*, Lam. (Mean of both seasons)

Seawater %	Dry aerial parts (g)			Leaf number			Leaf area (dm^2)		
	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean
0	48.70b	42.32e	45.50b	14.85a	10.26f	12.56b	19.93b	18.84e	19.38b
10	52.41a	40.66f	46.39a	14.51b	11.18e	12.85a	20.64a	18.88d	19.76a
15	44.56c	37.90h	41.20c	12.72c	9.80g	11.26c	19.75c	18.51g	19.13c
20	43.67d	34.77i	39.22d	11.83d	9.67h	10.75d	18.81f	17.57h	18.19d
25	38.85g	26.85j	32.87e	9.80g	7.48j	8.64e	15.66i	10.87j	13.27e
50	26.85j	25.71k	26.30f	7.74i	7.05k	7.40f	8.80	9.68k	9.24f
Mean	42.50a	34.70b		11.90a	9.20b		17.26a	15.72b	

Note. $dm^2 = cm^2 \times 0.01$; Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

Table 5. Effect of soil type and diluted seawater irrigation on leaves and roots fresh and dry weights of *Moringa oleifera*, Lam. (Mean of both seasons)

Seawater %	Leaf fresh weight (g)			Leaf dry weight (g)			Root fresh weight (g)			Root dry weight (g)		
	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean
0	51.64b	46.29f	48.97b	16.09d	14.76d	15.43c	280.01j	285.20i	282.60f	46.89h	55.82f	51.35d
10	54.61a	47.94e	51.28a	18.13a	15.18e	16.66a	274.93k	298.44g	286.70e	46.89h	55.82f	51.35d
15	50.70c	38.60h	44.65c	16.83b	14.60g	15.72b	297.66h	311.57f	304.60d	47.64g	77.53e	62.58c
20	48.33d	38.11i	43.22d	16.23c	14.02i	15.13d	330.05e	346.04c	338.00c	79.88d	85.03b	82.46b
25	42.65g	37.08j	39.86e	14.22h	12.83j	13.52e	347.48b	364.71a	356.10a	82.90c	85.57a	84.24a
50	36.74k	33.97l	35.35f	12.45k	12.41l	12.43f	335.60d	364.71a	350.20b	34.62j	43.60i	39.11e
Mean	47.40a	40.30b		15.70a	14.00b		311.00b	328.40a		56.50b	67.20a	

Note. Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

ii. Diluted seawater: Data (Tables 3 and 5) revealed that lower percent (10 and 15%) seawater in the irrigation gave equally good as freshwater in most studied growth characters for both areas. There was a negative relationship between seawater percent and most plant growth characters. Results were taken to gradually decline with the increase in the proportion of seawater until it reached a very low level unviable economically when the seawater percentage was 50% of the irrigation water. The ratio of 10% seawater at Kafr El-Sheikh area gave the tallest plants (168.43 cm), thickest stem (2.05 cm) and heaviest fresh and dry aerial parts while, fresh water only excelled in some growth characters as stem diameter (1.88 cm) and aerial parts dry weight (42.32 g) at Balteem area and leaves number (14.85) at Kafr El-Sheikh area. Negative relationship was shown between salt stress and plant growth characters i.e. plant height, green leaves area and dry weight of each root, stem, leaves and shoots which decreased as the salt concentration increased in the diluted seawater (Hussein et al., 2010; Hussein & Abou-Baker, 2014). It was noticed from chemical analysis of seawater table that, seawater contain many fertilizer elements which may be encouraged plant growth. Fresh and dry weights of the tested plants increased with increasing concentration of seawater used for irrigation from 10% up to 15%. But further increase in salinity level of the irrigation water tended to decrease the fresh and dry weights (Ashour et al., 1997 on the grass species). The decrease in photosynthesis under saline conditions is considered as one of the most important factor responsible for reduction of plant growth (Ball et al., 2004).

Also, leaf area and leaves fresh and dry weights take the same trend in the both areas as record 20,64 and 18,88 dm^2 for leaf area, 54.61 and 47.94 g and 18.13 and 15.18 g for fresh and dry weights, respectively (Tables 4 and 5). This was followed by freshwater treatment in most cases which gave results equal or slightly less than 10% seawater treatment. The stimulatory effect of moderate salinity on the growth of some halophytic plants was also reported by O'Leary (1988), and may be attributed to improved shoot osmotic status as a result of increased ion uptake (Naidoo et al., 1995). Data show that, both root fresh and dry weights gradually increased with increasing seawater percentage till 25% seawater then, started to decrease at 50% seawater. This may be due to the increase in salinity stress with increasing seawater percentage in irrigation water. The increase in root fresh and dry weights at higher salinity suggests that, moringa roots have tendency to expansion and elongation under stresses conditions (Flowers & Hajibagheri, 2001; Akhtar et al., 2003). Nouman et al. (2012) found that under saline environment, *Moringa oleifera* roots showed more ramification. Innocent Pahla et al. (2013) revealed different responses of *M. oleifera* in different soils. Root mass of 14 and 26.9 g were recorded in sandy and clay soils. They stated that, low yields in sandy soils compared to clay soils can be attributed to low soil nutrients.

3.2.2 Effect on Leaves Chemical Constituents

Total green color, total carbohydrates and mineral contents in moringa leaves were significantly affected with not only the increase in seawater percentage in the irrigation water but also the different experimental areas. Kafer El-Sheikh area recorded the best results for most studded chemical constituents. While the excellence fluctuations between each of the two seawater percentages of 0 and 10%, as seawater 0% recorded the highest values for total green color and total carbohydrates contents whereas, seawater 10% excelled in total soluble protein content. The three the abovementioned contents were gradually decline with the increase in seawater percentage.

Moringa plants that were irrigated with low diluted seawater percentage (10%) at Kafr El-Sheikh area gave the absolutely highest total green color , total soluble protein and total carbohydrates contents as recorded 37.48 SPAD, 3.76 mg/100 g.d.w and 14.99 g/100 g.d.w, respectively (Table 6). Salinity caused reduction in chlorophyll content in combination with the reduced leaf area and growth (Shoresh et al., 2011). The photosynthesis is the most severely affected processes through salinity stress (Sudhir & Merthy, 2004). Salt affects the photosynthesis apparatus but the researchers are still unclear about the factors, which are responsible for the inhibition of photosynthetic activity (Steduto et al., 2000). Also, Anwar et al. (2006) found no significant variation in the moringa protein contents from saline and non-saline areas.

Table 6. Effect of soil type and diluted seawater irrigation on total green color, leaf protein and total carbohydrates of *Moringa oleifera*, Lam. (Mean of both seasons)

Seawater %	Total green color (SPAD)			Total soluble protein (mg/100 g.d.w.)			Total carbohydrates (g/100 g.d.w.)		
	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean	Kafrelsheikh	Balteem	Mean
0	36.84c	36.96b	36.90a	3.70b	3.13i	3.42b	14.91b	14.13d	14.52a
10	37.48a	36.22f	36,80b	3.76a	3.21g	3.49a	14.99a	13.62f	14.31b
15	36.49e	33.71g	35.10d	3.68c	3.15h	3.42b	14.57c	13.36g	13.97c
20	36.83d	33.50i	35.17c	3.49e	3.08j	3.29c	14.05e	12.50i	13.27d
25	33.17j	33.68h	33.42e	3.41f	3.00k	3.21e	13.20h	12.33j	12.76e
50	31.76l	33.01k	32.39f	3.50d	2.96l	3.23d	12.08k	12.04l	12.06f
Mean	35.40a	34.50b		3.60a	3.10b		14.00a	13.00b	

Note. Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

It was noticed that, phosphorous, sodium and calcium contents gradually increased, while a significant depressions in K, Mg and nitrogen content in both experimental areas with increasing seawater % (Table 7). Kafer El-Sheikh area surpassed Balteem area in all cases. Seawater 10% was the best for N%, K% and Mg mg/100g whereas, seawater 50% gave the best results for both phosphorus and sodium contents. There were no significant differences among seawater at 10 or 20% for calcium contents. The highest phosphorous (0.69 pecent) and sodium (87.4 mg/100 g) contents were recorded when 50% seawater used at Kafer El-Sheikh area. Calcium contents gave constant values at low seawater percentages (10-20%) then begin to gradually decrease at both studied areas.

Table 7. Effect of soil type and diluted seawater irrigation on mineral constituents of *Moringa oleifera*, Lam. leaves (Mean of both seasons)

Seawater %	N%			P%			K%		
	Kfs	Balt	Mean	Kfs	Balt	Mean	Kfs	Balt	Mean
0	3.08c	2.36g	2.72c	0.46k	0.41l	0.44e	2.19c	1.00i	1.60c
10	3.36a	2.99d	3.18a	0.49i	0.47j	0.48d	2.31a	1.12g	1.72a
15	3.11b	2.58f	2.85b	0.53g	0.55f	0.54c	2.23b	1.08h	1.66b
20	2.66e	2.14h	2.40d	0.57d	0.51h	0.54c	2.03d	0.95j	1.49d
25	1.89i	1.80j	1.85e	0.66b	0.56e	0.61b	1.96e	0.78k	1.37e
50	1.63k	1.31l	1.47f	0.69a	0.62c	0.66a	1.27f	0.75l	1.01f
Mean	2.60a	2.20b		0.60a	0.50b		2.00a	0.90b	
Seawater %	Na (mg/100 g)			Ca (mg/100 g)			Mg (mg/100 g)		
	Kfs	Balt	Mean	Kfs	Balt	Mean	Kfs	Balt	Mean
0	16.5k	16.2l	16.3f	322f	325e	324c	851e	735k	793e
10	24.9i	19.4j	22.2e	328d	331b	330ab	1102a	955d	1029a
15	37.2g	28.7h	32.9d	330c	328d	329b	1030b	788g	909b
20	59.6d	41.0f	50.3c	333a	328d	331a	958c	743j	851c
25	75.5b	56.3e	65.9b	284g	252i	268d	833f	757i	795d
50	87.4a	68.9c	78.1a	260h	226j	243e	759h	690l	724f
Mean	50.2a	38.4b		310a	298b		922a	778b	

Note. Kfs = Kafrelsheikh; Balt = Balteem; Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

The highest nitrogen, potassium and magnesium values were obtained when 10% seawater at Kafer El-Sheikh area was used. A positive correlation was found between both Na and P contents and seawater percentage, while K, Ca and Mg were negatively correlated with seawater percentage. This may be due to that, at low percentages of seawater, plants could benefit of seawater minerals which considered as cheap fertilizer, which reflected as an improvement on plant growth. These results are in harmony with those obtained by Garg and Gupta (1996) as they reported that, salinity depressed N and K uptake while Na contents increased. The excessive Na inhibits the uptake of other essential minerals like K, Ca and Mg (Al-Karaki, 2000). The adverse effect of salinity on growth may be causes through three ways: reduced the available water in the root zone causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance depressing uptake and transport of nutrients and Na^+ competes K^+ for binding sites essential for cellular function (Munns & Tester, 2008). Accumulation of inorganic solutes, such as sodium and potassium can also play a role independently or in combination with other mechanisms in maintaining the osmotic imbalance caused by the salt stress and influence the osmotic potential adjustment of plant cells (Peng et al., 2004; El-Mahrouk et al., 2010) on buttonwood. Nitrogen content was significantly reduced by salt stress, especially in the leaves (Geissler et al., 2009).

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