*International Journal of Plant & Soil Science*
*3(2): 163-177, 2014; Article no. IJPSS.2014.004*

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# Growth and Mineral Status of Moringa Plants as Affected by Silicate and Salicylic Acid under Salt Stress

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author JS designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author CKT managed the literature searches, analyses of the study performed the spectroscopy analysis and MM managed the experimental process and MA identified the species of plant. All authors read and approved the final manuscript.*

***Original Research Article***

***Received 23rd July 2013***
***Accepted 24th August 2013***
***Published 29th November 2013***

## ABSTRACT

For evaluation of moringa growth and its minerals content response to irrigation with diluted seawater and spraying by potassium silicate solitary (Si) or in combination with salicylic acid (Si+SA), a pot experiment was conducted in the greenhouse of the National Research Center, Cairo, Egypt. Negative relationship was shown between salt stress degree and plant growth characters i.e. plant height, leaves area and dry weight of root, stem and leaves, which decreased as the salt concentration increased in the diluted seawater. Nevertheless, shoot/root ratio and leaf water content were increased with salinity increased. All growth characters increased with Si+SA addition. While adding sole silicate gave more plant height than the combined application without significant difference between them. The highest positive effect was shown when plants irrigated by tap water and spraying with Si+SA together. Significant depressions were obtained in nitrogen concentration or content as a result of growing moringa plants under salinity condition. Similar response in P content but the differences were not significant. Calcium and K concentrations did not significantly responded with salinity but Mg concentration decreased significantly only with the first level of salinity. Calcium showed its higher

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increment in content by spraying single Si under fresh water treatment. In most cases, application of potassium silicate in combination with salicylic acid gave the higher increases in mineral content estimated in this work. This means that, a synergistic effect was found between these two materials.

*Keywords: Moringa (Moringa oleifera Lam.); salinity; salicylic acid; potassium silicate; growth; mineral status.*

## 1. INTRODUCTION

One of the most urgent global problems is finding enough water and land to support the world's food needs. Clearly, we need alternative sources of water and land on which to grow crops. Seawater agriculture is defined as growing salt-tolerant crops on land using water pumped from the ocean for irrigation. There is no shortage of seawater: 97 percent of the water on earth is in the oceans [1]. In this Mediterranean region, where protected horticulture is one of the most important economic sectors, irrigation with saline water has been put into practice to improve the quality of fresh tomato [2].

Oil seed plants if found suitable irrigation with saline water or/and treated wastewater, may be high economic alternative to the traditional field crops [3,4]. Salinity is known to affect several aspects of plants, morphological, biochemical and anatomical structure of plants [3,5,6]. Moringa (*Moringa oleifera* Lam.) is cultivated for multiple purposes because all its parts including seeds, stems, shoots, leaves, flowers, fruits and roots are useful [7]. Leaves with high protein and seeds contain 30 to 40% oil that is high in oleic acid, while degreased meal is 61% protein [8]. Moringa tree is even drought and salt tolerant and low nutrients requirements [9,10].

Salicylic acid (SA) was first discovered as a major component in the extracts from Salix (willow) whose bark from ancient time [11]. It is a plant growth regulator (PGR) that part of signaling pathway induced by several biotic and abiotic stresses. It has been identified as an endogenous regulating signal in mediating plant defense against pathogens. It's also a natural signal molecule for activation of defense mechanism [12,13,14]. Application of SA has been shown to improve plant stress tolerance. A plethora of research demonstrates protective effects of exogenous SA application on plants against salinity [15,16].

Silicon (Si) in soils can vary considerably from 1 to 45 % [17], and found in plants at concentrations ranging from 0·1 to 10 % (dry weight basis) [18]. Silicic acid is generally found in soils at concentrations ranging from 0·1 to 0·6 mM [18,19]. Silicon promotes the growth of various higher plants [20]. Its uptake and role as an alleviator of biotic and abiotic stress were reported by Ma, [21] and [22]. In accordance with Liang et al., [23] oxidative damage induced by salt may be alleviated by Si addition. Potassium silicate contains no volatile organic compounds, and applications will not result in the release of any hazardous or environmentally persistent by products [24].

There are numerous studies on the application of both silicates and salicylic acid individually. While no information about a role of the combination between silicate and salicylic in alleviating salt stress. Therefore, this work designed to investigate the effect of potassium silicate, salicylic acid and the combination between them on growth and mineral status of moringa plants irrigated by diluted seawater.

## 2. MATERIALS AND METHODS

A pot experiment was conducted in the greenhouse of the National Research Center to evaluate the effect of salt stress and foliar amendments on growth and mineral status of moringa plants. The treatments were as follows:

Salinity treatments

1. Tap water, 285 ppm ($S_0$)
2. Irrigation by diluted seawater 2000ppm ($S_1$)
3. Irrigation by diluted seawater 4000ppm ($S_2$)

Foliar treatments

1. Spraying with distilled water (Control)
2. Spraying with 300 ppm $SiO_2$ (Si) as potassium silicate
3. Spraying with 300 ppm $SiO_2$ + 300ppm salicylic acid (Si+SA)

Moringa (*Morirga alifera* Lam.) seeds were sown in April 1$^{st}$ 2012. Soil sample was taken from Kerdasa region, Giza Governorate, air-dried, crushed, sieved to pass through 2mm sieve and preserved for analysis. Some physical and chemical characteristics of the investigated soil were given in Table (1). Every pot received 8kg soil, 1.80g of ammonium sulphate (20.6%N), 1.5g calcium super phosphate (15.5% $P_2O_5$) and 0.5g potassium sulfate (48.5% $K_2O$). Plants were transplanted to these pots at 21 day from sowing, thinned twice after one and two weeks from transplanting and left one plant/pot in 8 replicates for each treatment. The irrigation with saline water was started at 45 days from sowing. Some chemical properties of used seawater were shown in Table (2). Foliar application treatments were applied at two successive times 60 and 90 days after sowing. At 180 day from sowing, three plants were picked from each treatment, divided to root, stem and leaves and weighted. Plant samples were cleaned dried in electric oven at 70°C, and ground in stainless steel mill.

**Table 1. Some physical and chemical characteristics of the investigated soil**

| Characteristics | Values |
|---|---|
| Chemical properties | |
| pH (1 : 2.5 soil : water ratio) | 7.15 |
| EC (Soil paste extraction) $dSm^{-1}$ | 1.30 |
| Soluble cations (me./100g): | |
| Calcium | 2.38 |
| Magnesium | 1.27 |
| Potassium | 0.23 |
| Sodium | 1.82 |
| Soluble anions (me./100g): | |
| Carbonate | - |
| Bicarbonate | 0.91 |
| Chloride | 1.90 |
| Sulphate | 1.89 |
| Physical properties (%): | |
| Organic matter | 1.30 |
| Calcium carbonate | 2.53 |
| Sand | 21.5 |
| Silt | 30.2 |
| Clay | 48.3 |
| Textural class | Clay |

**Table 2. Some chemical properties of used seawater**

| Characteristics | Values |
|---|---|
| pH | 8.4 |
| EC ($dSm^{-1}$ ) | 50 |
| Cations (g/L): | |
| Calcium | 0.42 |
| Magnesium | 1.31 |
| Potassium | 0.42 |
| Sodium | 11.02 |
| Anions (g/L): | |
| Bicarbonate | 0.12 |
| Chloride | 19.88 |
| Sulphate | 2.74 |

The following measurements were recorded: plant height (cm), leaves area ($cm^2$), dry weight of root, stem, leaves and shoot (above ground parts). Shoot/root ratio and leaves water content% was calculated as the difference between plant fresh weight and plant dry weight [25]. Dry powder was digested and analyzed for N, P, K, Na, Ca and Mg as described by [26]. Analysis of variance (ANOVA) and least significant difference (LSD) at 0.05 probability level was computed using the CoStat program and applied as described by [27].

## 3. RESULTS AND DISCUSSION

### 3.1 Growth Parameters

#### 3.1.1 Effect of salinity

Negative relationship was shown between salt stress degree and plant growth characters i.e. plant height, green leaves area and dry weight of root, stem, leaves and shoot which decreased as the salt concentration increased in the diluted seawater. Root and stem dry weights were more affected by salinity than any other growth parameters (Table 3). Where, the decrease percentage were 2.9 and 9.4%, 8.2 and 17.7%, 23.6 and 25.6%, 15.4 and 20.6%, 2.3 and 15.0% and 11.3 and 18.7% for plant height, leaves area, root, stem, leaves and shoot of plants irrigated by $S_1$ and $S_2$, respectively. Nevertheless, shoot/root ratio and plant water content in dry weight basis was increased with salinity increased. Leaves water content values were arranged in the order: $S_2>S_1>S_0$.

Hussein et al. [6] confirmed these results on Jatropha. The growth and mineral uptake are altering extensively in plants grown under salinity stress [28]. Plant growth is reduced when essential mineral nutrients become limited or are in excess. The reduction of plant growth due to salinity could be the indirect consequence of its influence in the metabolism of mineral nutrients, resulting in nutrient imbalance and physiological disorders. The adverse effect of salinity on growth may be causes through three ways [29], 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. The depression in photosynthetic is the most severely affected processes through salinity stress [30] which is mediated through a stomatal conductance, internal $CO_2$ partial [31] and stomatal that affect gaseous exchange [32]. The decrease in photosynthesis under saline conditions is considered as one of the most important factor responsible for reduction of plant growth [33].

**Table 3. Effect of salinity, foliar treatments and the interaction between them on growth of moringa plants**

| Salinity treatment (S) | Foliar treatment (F) | Plant height (cm) | Leaves area | Dry weight g/plant | | | | Shoot/Root ratio | Leaves water content % |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Root | Stem | Leaves | Shoot | | |
| $S_0$ | Control | 136 | 778 | 2.04 | 5.43 | 1.94 | 7.37 | 3.61 | 79.3 |
| | Si | 143 | 857 | 2.05 | 7.26 | 4.08 | 11.34 | 5.53 | 76.7 |
| | Si+SA | 134 | 1057 | 2.46 | 9.33 | 4.39 | 13.72 | 4.18 | 76.3 |
| Mean | | 138 | 897 | 2.18 | 7.34 | 3.47 | 10.81 | 4.44 | 77.4 |
| $S_1$ | Control | 132 | 754 | 1.66 | 4.12 | 2.47 | 6.59 | 3.97 | 79.0 |
| | Si | 138 | 865 | 1.87 | 5.53 | 3.78 | 9.31 | 4.98 | 76.7 |
| | Si+SA | 131 | 850 | 2.1 | 8.97 | 3.91 | 12.88 | 6.13 | 78.7 |
| Mean | | 134 | 823 | 1.88 | 6.21 | 3.39 | 9.59 | 5.03 | 78.1 |
| $S_2$ | Control | 124 | 819 | 1.12 | 5.44 | 2.47 | 7.91 | 7.06 | 80.0 |
| | Si | 126 | 746 | 1.99 | 6.03 | 2.79 | 8.82 | 4.43 | 79.3 |
| | Si+SA | 126 | 650 | 2.38 | 6.03 | 3.6 | 9.63 | 4.05 | 77.0 |
| Mean | | 125 | 738 | 1.83 | 5.83 | 2.95 | 8.79 | 5.18 | 78.8 |
| Mean of foliar treatments | Control | 131 | 783 | 1.61 | 5.00 | 2.29 | 7.29 | 4.88 | 79.4 |
| | Si | 136 | 823 | 1.97 | 6.27 | 3.55 | 9.82 | 4.98 | 77.6 |
| | Si+SA | 130 | 852 | 2.59 | 8.11 | 3.97 | 12.08 | 4.79 | 77.3 |
| $LSD_{5\%}$ | S | NS | 109 | 0.92 | NS | NS | NS | NS | 0.8 |
| | F | NS | 124 | 0.58 | 1.24 | 0.95 | 2.52 | NS | 0.8 |
| | S x F | NS | 212 | NS | 2.36 | NS | NS | NS | 1.5 |

*$S_0$=tap water, $S_1$=diluted seawater 2000ppm, $S_2$=diluted seawater 4000ppm, Control= distilled water, Si= 300 ppm $SiO_2$ and Si+SA = 300 ppm $SiO_2$ + 300ppm salicylic acid.*

### 3.1.2 Effect of foliar treatments

Data presented in Table (3) indicated that, irrespective of salinity treatments, all growth characters increased with Si+SA addition followed by sole silicate application and the next is the control. Shamsul and Aqil [11] mentioned that SA is a phenol, ubiquitous in plants generating a significant impact on plant growth and development, photosynthesis, transpiration, ion uptake and transport and also induces specific changes in leaf anatomy and chloroplast structure. Hussein et al. [34] demonstrated that sprayed maize plants with 200ppm SA improved all growth criteria and improved growth, chlorophyll *a* and *b* pigments, leaf turgor potential, and leaf and root $Ca^{2+}$ concentrations. While, potassium silicate produced higher plant height values than other foliar treatments. Shoot/root ratio not affected significantly by foliar application. Although, both of sole Si application and Si+SA treatment decreased leaves water content significantly compared to control without significant different between them. The beneficial effects of Si are mainly associated with its high deposition in plant tissues enhancing their strength and rigidity [19]. In this concern, [35] showed that, silicon significantly increased shoots height of wheat plants. Application of the mixture proved inhibitory effect on plant height and may be reflect on cell extension or division, which is in same line with those obtained by salinity effect. SA treatments had effects on plant growth and dry matter/ plant. The greatest stem diameter, leaf dry matters were obtained from 0.50 mM SA treatment [36].

### 3.1.3 The interaction effect between salinity and foliar treatments

Both of Si and conjunction of it and SA increased growth parameters under $S_0$, $S_1$ and $S_2$ treatments, except leaves area of plants treated with Si and Si+SA and irrigated by high salinity treatments ($S_2$) as illustrated in Table (3). The increase percentage of root, stem and leaves by addition of Si and (Si+SA) compared to control were illustrated in Fig. (1) and indicated that, the increase percentage of root enhanced by addition of Si and Si+SA with raising the salinity of irrigation water, while the reverse was true for leaves dry weight. The highest values of root, stem, leaves and shoot were observed by addition of Si+SA mixture to plants which irrigated by tape water. In contrast, the highest shoot/root ratio and leaves water content recorded in water spraying treatment under high salt stress ($S_2$).

Romero-Aranda et al. [25] noticed that leaf turgor potential and net photosynthesis rates were 42 % and 20% higher in salinized plants supplied with Si. Dry matter was substantially reduced at the highest salinity treatment (680 mM) but it was not affected in plants treated with 500 µM silicon [37]. Similar response was evident in mean relative growth rate, nevertheless, leaf elongation decreased with salinity concentration in both silicon treatments but this effect was more acute in the absence of silicon addition. When focus on control treatment (distilled water sprayed plants) under $S_0$, $S_1$ and $S_2$ salinity treatments, it can be concluded that, most growth parameters decreased by $S_1$*control except leaves dry weight and shoot/root ratio. Also, all growth parameters turned to be increased by $S_2$*control except plant height and root dry weight. This could be attributed to 1) Leaves are the most affected part with distilled water spraying, 2) Spraying with distilled water increased moringa salt tolerance and increase its useful of seawater as a nutrient supplementary solution, El-Mahrouk et al., [38] reported that diluted seawater up to 30% improved the most stem and leaf structure parameters of buttonwood plant (*Conocarpus erectus* L.) when compared with low and high seawater levels, 3) Moringa has a ability to survival with salinity condition, 4) Mathematically, increasing shoot/root ratio means that decreasing of root dry weight, this confirm the result of root dry weight, hence decreasing root weight tend to decrease the denominator of equation, subsequently increase the net result, 5) Roots are the most part affected with salinity stress and not affected directly with water spraying. Sometimes, addition of Si solitary or conjunction with SA increased some growth parameters with increasing salinity compared to $S_0$, while this result was fluctuated and didn't take a stable trend. In this concern [19] concluded that, Si plays an astonishingly large number of diverse roles in plants, and dose so primarily when the plants are under stressful conditions, whereas under benign conditions its role is often minimal or even nonexistent. Furthermore, Moussa [39] indicated that silicon partially offset the negative impacts and increased tolerance of maize plants to NaCl stress by enhancing SOD and CAT activities, chlorophyll content and photosynthetic activities. The toxic effect generated by salt stress (50 mM NaCl) were completely overcome by the application of SA treatment whereas, the effect of high concentration of NaCl were reduced partially by SA [40].

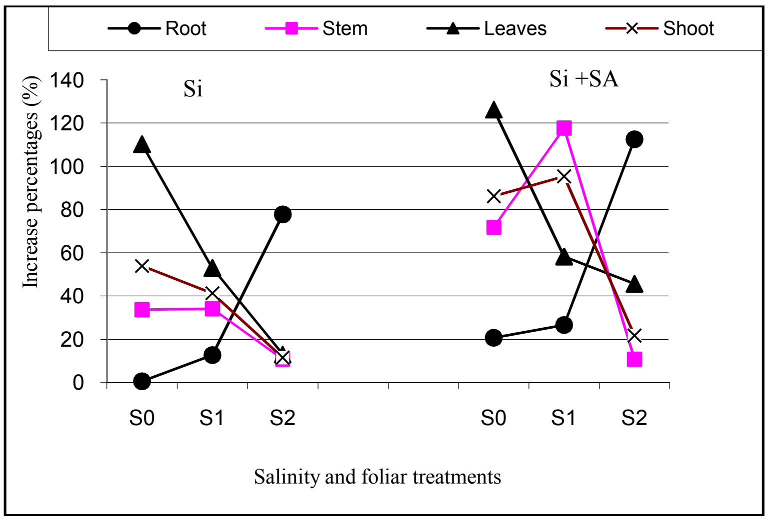


**Fig. 1. The increase percentages (%) of root, stem, leaves, and shoot by addition of Si and (Si+SA) compared to control.** *$S_0$=tap water, $S_1$=diluted seawater 2000ppm, $S_2$=diluted seawater 4000ppm, Control= distilled water, Si= 300 ppm $SiO_2$ and Si+SA = 300 ppm $SiO_2$+300ppm salicylic acid.*

## 3.2 Mineral Status

### 3.2.1 Effect of salinity

Significant depressions were obtained in nitrogen concentration as a result of growing moringa plants under salinity condition (Fig. 2). Other analyzed nutrients seemed to be without significant effect with salt stress treatments, but Mg concentration decreased significantly only with the first level of salinity. Similar responses in P and K concentrations were observed. On the other side, Na concentration was significantly increased with irrigation by seawater compared to $S_0$ and without significant difference between two salinity levels ($S_1$ and $S_2$). Although, Ca concentration not affected significantly by salinity level, it increased gradually with increasing concentration of seawater. Diluted seawater up to 30% improved N, P and Fe concentration in aerial parts of buttonwood plant when compared with low and high seawater levels, but 10% seawater treatment increased K level [38].

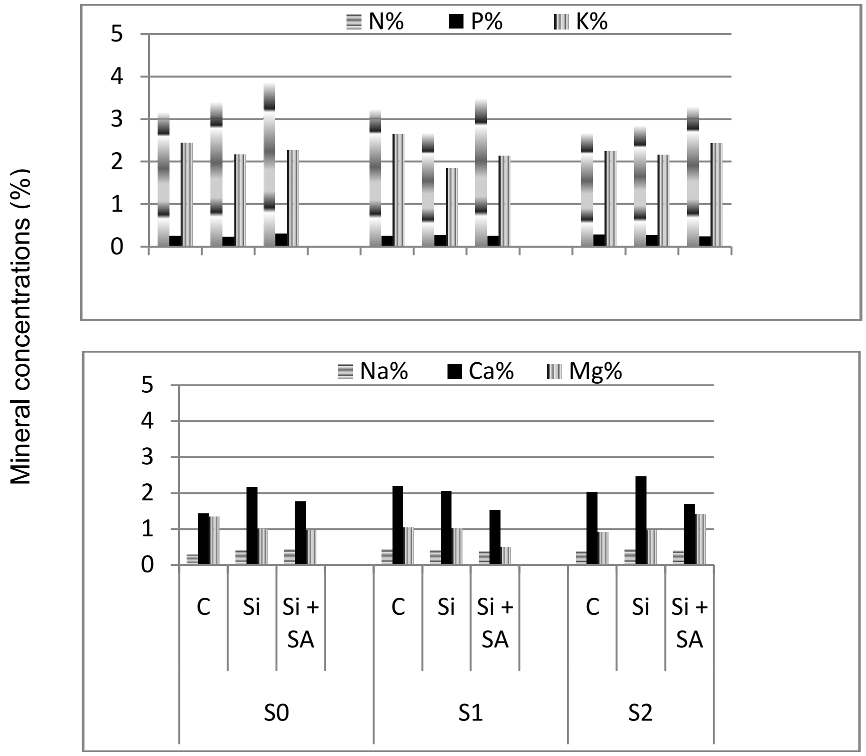


**Fig. 2. Minerals concentration as affected by salinity, foliar treatments and the interaction between them.**

*$S_0$=tap water, $S_1$=diluted seawater 2000ppm, $S_2$=diluted seawater 4000ppm, Control= distilled water, Si= 300 ppm $SiO_2$ and Si+SA = 300 ppm $SiO_2$+300ppm salicylic acid.*

As for mineral contents (Table 4), N, P, K, Na and Ca content decreased with increasing salinity level with significant difference in N and without significant difference in other nutrients. Mg content followed the same trend of its concentration and decreased only with the first level of salinity but without significant difference. Crop performance may be adversely affected by salinity induced nutrients disorder. However, the relation between salinity and minerals nutrition of crops are very complex [41]. Numerous studies were conducted and reported the disorder in nutrients as a result of salt stress [42,43].

### 3.2.2 Effect of foliar treatments

Regardless salinity effect, P and Ca concentrations not affected significantly with spraying both of Si and Si+SA treatments. While, other minerals concentrations affected significantly with foliar treatments (Fig. 2). The highest N and P concentrations gained by addition of the mixture. Silicon was increased N, P and K concentrations in shoots and grains of rice [44] and wheat [35]. Foliar application of salicylic acid (SA) at 200 and 400 mg/l counteracted the adverse effect of salinity, this accompanied generally by significant increases in plant growth [45]. The highest Na and Ca obtained by sole Si application compared to the mixture. This may be attributed to SA decreased Na and Ca concentrations more than Si solitary application. Potassium concentration declined significantly by the order: control> Si+SA>Si. This finding may be refer to 1) Low values of leaves dry weight in control treatment render the K more concentrated, Rasheed et al., [46] confirmed this finding for P element and reported that P concentration in control plants increased since little growth raised the concentration. 2) Potassium silicate is considered a source of Si and K in addition to, SA may ameliorate the negative effect of salinity by increasing K accumulation. Potassium has a significant role in improving plant water status and mitigating the toxic effects of Na. Silicon concentration was positively correlated with K concentration in shoots [47]. The increase in concentration of K and Ca in plants under salt stress could ameliorate deleterious effects of salinity on growth [41]. Yıldırım and Dursun [36] found that SA application inhibited Na accumulation, but stimulated N, P and K. There are many factors change the mineral status of moringa leaves, so it becomes very difficult to link between concentrations values and studied factors.

Concerning mineral content, the application of both materials induced more increment in different nutrients content followed by sole Si application, except Ca content (Table 4). Calcium content was increased by addition of potassium silicate individually. In contrast, [48] mentioned that Si had no direct effect on P uptake. Khan [49] pointed out that, the decrease in $Na^+$ and $Cl^-$ content with 0.5 mM SA application was 27.2% and 28.3% with respect to the control, while this treatment resulted in the increase of N by 32.7%, P by 75.0%, K by 32.3%, and Ca by 43.6%, in comparison to the control. The application of 1.0 mM SA did not alleviate the negative effects of NaCl on ions and nutrients content.

**Table 4. Nutrients content (mg/plant) as affected by salinity, foliar treatments and the interaction between them**

| Salinity treatments | Foliar treatments | N | P | K | Na | Ca | Mg |
|---|---|---|---|---|---|---|---|
| $S_1$ | C | 61.9 | 4.97 | 46.88 | 5.95 | 28.27 | 26.13 |
| | Si | 137.9 | 9.60 | 87.72 | 16.98 | 88.40 | 40.20 |
| | Si + SA | 170.0 | 13.59 | 99.14 | 18.84 | 77.77 | 42.13 |
| Mean | | 123.3 | 9.39 | 77.91 | 13.92 | 64.81 | 36.16 |
| $S_2$ | C | 79.9 | 6.30 | 65.40 | 10.78 | 53.80 | 26.23 |
| | Si | 102.5 | 10.02 | 69.51 | 15.80 | 75.30 | 37.83 |
| | Si + SA | 137.7 | 10.06 | 84.06 | 15.08 | 60.90 | 18.70 |
| Mean | | 106.7 | 8.79 | 72.99 | 13.89 | 63.33 | 27.59 |
| $S_3$ | C | 65.5 | 6.98 | 55.36 | 9.51 | 50.07 | 22.50 |
| | Si | 79.0 | 7.61 | 59.99 | 12.03 | 69.03 | 26.90 |
| | Si + SA | 117.7 | 8.77 | 87.55 | 14.45 | 61.27 | 51.23 |
| Mean | | 87.4 | 7.79 | 67.63 | 11.99 | 60.12 | 33.54 |
| Mean of foliar treatments | C | 69.1 | 6.08 | 55.88 | 8.75 | 44.04 | 24.96 |
| | Si | 106.5 | 9.08 | 72.41 | 14.93 | 77.58 | 34.98 |
| | Si + SA | 141.8 | 10.81 | 90.25 | 16.12 | 66.64 | 37.36 |
| $LSD_{0.05}$ | S | 26.6 | NS | NS | NS | NS | NS |
| | F | 26.6 | 1.62 | 13.46 | 2.42 | 13.58 | 8.32 |
| | F*S | NS | 2.81 | NS | 4.19 | NS | 14.4 |

*$S_0$=tap water, $S_1$=diluted seawater 2000ppm, $S_2$=diluted seawater 4000ppm, Control= distilled water, Si= 300 ppm $SiO_2$ and Si+SA = 300 ppm $SiO_2$+300ppm salicylic acid.*

### 3.2.3 The interaction effect between salinity and foliar treatments

The interaction between two studied factors (S*F) affected significantly P, K, Na and Mg concentrations, and without significant effect on N and Ca (Fig. 2). Sodium concentration increased by 37 and 40% under irrigation with fresh water, and by 13 and 5% under high salinity treatment, while decreased by 3 and 13% under 1st salinity treatment with application Si and Si+SA compared to control, respectively. This may be depend on 1) The concentration of Na in irrigation water, 2) The concentration of Si and SA in foliar solution, 3) Sensitivity of plant to salinity, 4) Kind of salt sources in irrigation water; if it synthetic chemicals or natural as seawater, which contain balanced concentrations of different minerals. Thus, the introduction of a controlled irrigation with diluted seawater can be an effective method to produce higher quality tomatoes in addition to face the scarcity and salinization of water resources [2]. One of the salt alleviation of silicon that it is reduced Na content through its effect on transpiration bypass flow [50]. Ameliorative effects of silicon were correlated with reduced sodium uptake [37]. Generally, N, P, K, Na, Ca and Mg concentrations in moringa leaves under studied factors and the interaction between them ranged between 2.67 and 3.86, 0.237 and 0.310, 1.85 and 2.64, 0.306 and 0.436, 1.43 and 2.47 and 0.5 and 1.41%.

As for mineral content (Table 4), the interaction between salinity in irrigation water and foliar application treatments affected significantly P, Na and Mg, while without significant difference on N, K and Ca values. Under all salinity treatments, the sprayed with Si+SA mixture increased mineral content followed by Si and the next is the control. This trend was support the results of growth parameters and reflect a synergistic effect between these two materials. In this concern, [51] found that foliar-applied SA improved turgor potential, and leaf and root $Ca^{2+}$ concentrations. Khan et al. [49] concluded that plants treated with 0.5 mM SA resulted in a maximum decrease in the content of $Na^+$, $Cl^-$, and leakage under saline conditions compared to the control. In contrast, this treatment increased N, P, K, and Ca content.

## 3.3 Mineral Ratios

### 3.3.1 Effect of salinity

Ratios of Na/K, Na/Mg, K/Mg and Ca/Mg follow the same trend: $S_1>S_2>S_0$ as affected significantly by salinity stress (Table 5). While, Na/Ca and K/Ca ratios decreased without significant difference in the order: $S_0>S_1>S_2$. Both of Ca/(Na+K) and Mg/(Na+K) ratio increased with increasing salinity stress $S_2>S_1>S_0$. Essa [52] reported that NaCl salinity may produce extreme ratios of Na/Ca and Na/K in the plants, causing them to be susceptible to osmotic and specific ion injury, as well as to nutritional disorders.

### 3.3.2 Effect of foliar treatments

Irrespective of salinity effect, the highest values of Na/K, Ca/Mg, Ca/(Na/K) and Mg/(Na+K) were gained by sole Si application. Free SA level in soybean increased with the addition of Si to salt treated plants [53]. While, the highest values of Na/Ca, Na/Mg and K/Mg were obtained by Si+SA mixture (Table 5).

**Table 5. Ratio of minerals (in concentration basis) as affected by salinity, foliar treatments and the interaction between them**

| Salinity treatments | Foliar treatments | Na/K | Na/Ca | Na/Mg | K/Ca | K/Mg | Ca/Mg | Ca/(Na+K) | Mg/(Na+K) |
|---|---|---|---|---|---|---|---|---|---|
| $S_1$ | C | 0.127 | 0.237 | 0.231 | 1.84 | 1.84 | 1.08 | 0.522 | 0.490 |
| | Si | 0.194 | 0.193 | 0.427 | 1.00 | 2.20 | 2.21 | 0.843 | 0.383 |
| | Si + SA | 0.190 | 0.244 | 0.451 | 1.29 | 2.38 | 1.85 | 0.656 | 0.356 |
| Mean | | 0.170 | 0.225 | 0.370 | 1.37 | 2.14 | 1.71 | 0.674 | 0.409 |
| $S_2$ | C | 0.165 | 0.203 | 0.436 | 1.23 | 2.63 | 2.23 | 0.716 | 0.336 |
| | Si | 0.228 | 0.210 | 0.419 | 0.93 | 1.85 | 2.03 | 0.904 | 0.444 |
| | Si + SA | 0.180 | 0.252 | 0.821 | 1.40 | 4.58 | 3.33 | 0.607 | 0.198 |
| Mean | | 0.191 | 0.222 | 0.559 | 1.19 | 3.02 | 2.53 | 0.742 | 0.326 |
| $S_3$ | C | 0.170 | 0.188 | 0.422 | 1.10 | 2.47 | 2.24 | 0.775 | 0.351 |
| | Si | 0.200 | 0.176 | 0.493 | 0.89 | 2.50 | 2.76 | 0.955 | 0.371 |
| | Si + SA | 0.165 | 0.239 | 0.289 | 1.46 | 1.76 | 1.21 | 0.599 | 0.496 |
| Mean | | 0.178 | 0.201 | 0.401 | 1.15 | 2.24 | 2.07 | 0.776 | 0.406 |
| Mean of foliar treatments | C | 0.154 | 0.209 | 0.363 | 1.39 | 2.32 | 1.85 | 0.671 | 0.392 |
| | Si | 0.207 | 0.193 | 0.446 | 0.94 | 2.18 | 2.34 | 0.901 | 0.399 |
| | Si + SA | 0.178 | 0.245 | 0.520 | 1.38 | 2.90 | 2.13 | 0.621 | 0.350 |
| $LSD_{0.05}$ | S | 0.01 | NS | 0.12 | NS 0.26 | 0.69 | 0.63 | NS | 0.07 |
| | F | 0.01 | NS NS | 0.12 | NS | NS | NS 1.08 | 0.12 | NS |
| | F*S | 0.02 | | 0.20 | | 1.19 | | NS | 0.12 |

*$S_0$=tap water, $S_1$=diluted seawater 2000ppm, $S_2$=diluted seawater 4000ppm, Control= distilled water, Si= 300 ppm $SiO_2$ and Si+SA = 300 ppm $SiO_2$+300ppm salicylic acid.*

### 3.3.3 The interaction effect between salinity and foliar treatments

All calculated ratios of mineral concentrations affected significantly by the interaction between two studied factors except Na/Ca, K/Ca and Ca/(Na+K). The values of mineral ratios are fluctuated under irrigation with fresh water. While, under 1st salinity level the highest values of all ratios obtained by Si+SA, except Na/K, Ca/(Na+K) and Mg/(Na+K) which reach to highest value with addition of single Si treatment (Table 5). Mahmood et al. [54] reported that, shoot and root $Na^{+}/K^{+}$ ratio though increased with increase in salinity levels, which was not reversed by exogenous supply of SA. The control treatment recorded the second level in all ratios under the highest salinity level, while sprayed materials fluctuated between 1st and 3rd rank. Generally, values of Na/K, Na/Ca, Na/Mg, Ca/(Na+K) and Mg/(Na+K) ranged between 0.127 and 0.955 and other ratios ranged between 0.89 and 4.58. Salt stress of seawater irrigation led to direct increase in sodium content and produced an increase in Na/K ratio in the aerial parts of buttonwood plant [38]. The effect of NaCl salt stress of callus showed ions distribution include Na, K, and Ca, ratio of Na/K. Salinity increased Na accumulation but K and Ca concentrations were reduced. K/Na ratio was significantly reduced at 50 mM NaCl and higher salinities [55].

## 4. CONCLUSION

This study suggests that, the mixture of potassium silicate and SA regulates moringa response to salt stress and may be used as a plant growth regulator to enhance plant growth and mineral status. Application of this novel mixture alleviate salt stress, gave highest growth parameters, maximum N and P concentrations, lowest Ca and Mg and moderate K and Na concentrations compared to control (spraying with distilled water). This means that, a synergistic effect was found between these two materials. Irrigation with diluted seawater (2000ppm) increased moringa growth parameters and enhance its mineral status, especially when spraying with distilled water. The present results warrant further studies to explore different concentrations of both silicate and salicylic to arrive at the appropriate mixing percentages.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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