International Journal of Agricultural Technology 2021Vol. 17(4):1241-1256
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

The synergistic effect of salinity and water depth on soil properties and maize productivity under foliar application of potassium silicate

Abdeen, S. A.*

Soils and Water Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

Abdeen, S. A. (2021). The synergistic effect of salinity and water depth on soil properties and maize productivity under foliar application of potassium silicate. International Journal of Agricultural Technology 17(4):1241-1256.

Abstract Soil salinity and water table depth are the most effective factors on soil features and crop productivity. The close relationship between salinity and water depth on soil characteristics, and maize productivity under foliar application of potassium silicate were investigated. The results showed that soil salinity and water table death in the studied sites were ranges between 1.27 to 5.30 $dS.m^{-1}$ and ≤65cm to ≤90cm, respectively. Also, pH, EC and total N in water table were ranged between 7.64 to 8.3, 5.80 to 9.80dSm^{-1} and 25.5 to 56.40$mg.l^{-1}$, respectively. Also, soil pH, OM and CEC, $CaCO_3$, and ESP in the successive layers of the studied soil profiles were fluctuated between 7.02 to 7.71, 0.20 to 0.84 % ,3.80 to 8.0 $cmol_c\ kg^{-1}$, 1.21 to 2.81% and 7.5 to 14.16%, respectively. On the other side, the field capacity (FC), saturated hydraulic conductivity (K*sat*) and bulk density (Bd) were ranged between 13 to 14.5% ,4.20 to 7.50 $cm.h^{-1}$, and 1.55 to 1.70 Mg m^{-3}, respectively. Addition that water table depth (≤65cm) in saline soil (>4 dSm^{-1}) reduced grain yield and chemical composition of maize as compared to water table depth (≤90cm) in non-saline soil (< 4 dSm^{-1}). Foliar application of potassium silicate gave a significant increase in the chemical composition and grain yield of maize grains. Nitrogen, phosphorous, potassium and crude protein were ranged between 1.25 to 2.11 %, 0.20 to 0.32 %, 1.10 to 1.63 % and 8.13 to 13.90 %, respectively. Maize yield ranged between 2033 to 2313 $kg.fed^{-1}$. The highest values were observed at non saline soil under 4% potassium silicate as compared to saline soil without application of potassium silicate. So, it was considerable that the potassium silicate can limited the side effect of soil salinity and water table.

Keywords: Water depth, Salinity, Soil characteristics, Maize productivity

Introduction

Irrigated agriculture in arid and semiarid locations has been plagued by salinity and waterlogging issues that endanger land sustainability as a result of rising water table depths or irrigation water overuse (Chhabra, 2005). Soil salinity in arid and semi-arid regions with a saline shallow water table is a

***Corresponding Author:** Sayed Abdelrahman Abdeen; **Email**: dr.sayedabdeen@azhar.edu.eg

serious problem. This is affected by soil quality of irrigation water and water table depth. The influence of water depth is due to its impact on capillary rise; the shallower the depth, the greater the contribution of groundwater to salinization (Jalili *et al.,* 2011). Previous studies have shown the reliance on water table depths of surface evaporative fluxes (Kamai and Assouline, 2018). Poor management of soil and water, inadequate drainage, and water table depth are effective factors causing accumulation of salts in soil which lead to un suitable media for plant growth and productivity (Schwabe *et al.,* 2006). The rise of water table, poor irrigation and agronomic practices lead to water logging and soil salinity due to the weak structure of saline soils; this results in adverse soil water-air-plant connections and limited nutrient availability for plants. Furthermore, salt stress has a negative impact on morphological and physiological processes in plants due to osmotic and ionic stress, as well as numerous biochemical reactions in plants (Semida *et al*., 2017). Capillarity-induced flow pathways transport water from the water table to the soil surface to supply the evaporative demand for shallow water tables (Tsypkin and Shargatov, 2018). In particular, arid, semi-arid agricultural areas are vulnerable to the effect of climate change on soil salinity, it's very important to identify patterns and formulating strategies for irrigation and crop management (Corwin, 2020). Salinity is abiotic stress, reducing the growth and yield of many crops (Abd El-Mageed and Semida, 2015). Salinity and water table can have a major impact on plant growth, survival and productivity where the effects depend on the period of saturated conditions, proportion of root zone affected, the limitation on root elongation, the rate at which oxygen is depleted, the effect on availability and nutrient uptake (El-Nashar, 2013). Changes in salinity and sodium affect the physical and chemical properties of soils, which subsequently alter nutrient availability (Wong *et al.,* 2005).

Maize *(Zea mays* L.*)* is importance crop due to its nutritional content especially because of the presence of high protein and also affected by soil salinity and nutrients loss. Nitrogen (N) losses represent not only environmental pollution but also additional economic costs to farmers. Increasing the nitrogen fertilizers to excessive amount one of the primary causes for N leaching (Zvomuya *et al.,* 2003). Nutrient losses raise many environmental concerns wherein it represents a decrease in the efficiency of the crop. Farmers often apply N fertilizer in excessive amounts in an attempt to maximize yields. This excessive N application results in a decrease in nitrogen use efficiency and pollutes the adjacent water (Yoo *et al.,* 2014). Crops differ in of their tolerance of salinity. Maize (*Zea mays* L.) was thought to be moderately salt sensitive (Carpici *et al.,* 2010).

Silicon (Si) is playing an important role against abiotic and biotic stresses. For instance, Si is effective in alleviating abiotic stresses, including salinity, drought, and temperature (Liang *et al.*, 2008). Also, Ali *et al.* (2012) found that foliar application of K-silicate has the potential to reduce the negative effects of drought stress on crops. Salim (2014) observed that silicon has a substantial role in enhancing growth and maize productivity as they are beneficial nutrients under abiotic stress. The foliar application rates of potassium silicate have many advantages for improving plant growth and yield; and photosynthetic efficiency (Ahmad *et al.*, 2013). Foliar application of potassium silicate had a significant effect on plant height, dry weight, nutrients and maize yield (Shedeed, 2018).

Problems with salinity caused by the presence of saline groundwater at shallow depths are widely recognized as adversely affecting the irrigated soil productivity, especially in arid and semi-arid regions. Further studies are needed on the effect of both water table depth and salinity on soil properties and productivity. The aim of this study was to investigate the synergistic effect of water table depth and salinity on soil characteristics, and maize productivity under foliar application of potassium silicate.

Materials and methods

Soil description

The experimental site was in a special farm at El - Rekabia, Damietta governorate, Egypt. Four soil profiles were selected from the studied area (40,000 m^2) and described.

Agricultural experiment

The current experiment was conducted in the summer season of 2019 to study the close relationship between both salinity and water depth on maize yield (*Zea mays* L., cultivar single hybrid 131) under foliar application rates of potassium silicate. Two sites were chosen to conduct the field experiments, representing two levels of salinity; site 1(non-saline soil), EC < 4 dS m^{-1} and site 2 (saline soil), EC > 4 dS m^{-1}), each site represented by 2 soil profiles. Water table depth (WTD) in the site 1; was ≤ 90 cm; and WTD in site 2 was ≤ 65. WTD was determined by observation graduated tape before planting (Morrison, 1983). The application rates of potassium silicate (0, 2 and 4 %). Four sites (each site was 10.50 m^2) with three replicates were chosen for represented the different levels of salinity and water table. Foliar sprays were applied every two weeks after planting until 90 days of the experiment. Liquid potassium silicate ($K_2\ SiO_3$) contains: 26.6% K_2O and 10.4% SiO_3. Two seeds were sow manually in each hole on two sides of the line, intra-hole spacing was 25 cm apart, irrigated immediately after sowing, then thinned to one plant in each hole and irrigated regularly every 10 - 15 days by furrow irrigation on small parallel channels which were create along the experimental areas. Cow manure was added at 10 ton.fed^{-1} (pH 6.88, EC 3.69 dSm^{-1}, OC 31.70 %, total N 2.25 %, P 0.58% and K 0.63%). Mineral fertilizers were applied at each site as follows; 120 N as a source of urea (46 % N). 200 kg.fed^{-1} of calcium superphosphate (15 % P_2O_5) was added during the preparation of soil. Potassium sulfates (48.5 % K_2O) were applied at rate of 50 kg fed^{-1} K_2O. After harvesting, five plants were randomly chosen from each plot and prepared for chemical analysis.

Soil and water analysis

Soil samples were collected from each site to determine the physical and chemical properties. The particle size distribution was determined by hydrometer method after dispersion with sodium hexametaphosphate as described by Gee and Bauder (1986). The bulk density was determined according to Grossman and Reinsch (2002) and calculated as:$Bulk\ density = \frac{M(\ Mg)}{V(m3)}$. Total porosity (assumed particle density ps = 2.65 Mg.m^{-3}) was calculated from bulk density (Bd), using the equation below: $TP\ (\%) = (1 - \frac{Bd}{ps}) \times 100$. Saturated hydraulic conductivity (K_{sat})was determined by using Darcy's equation for analysis of constant head method, as described by Youngs (2001), through the equation $Ksat\ (cm/h) = \frac{QL}{HAT}$. where Q= Volume of water passed through the column in cubic centimeter (cm^3), L= Length of the soil core in cm, H=Total height of the water column in cm, A = Cross-sectional area of the inner side of the tube in cm^2, T= Time of flow in hour. Soil pH was determined according to Thomas (1996). Cation exchange capacity (CEC) was determined by method described by Sumner and Miller (1996). Total soluble salts were determined used the method of Dellavalle (1992). Organic matter (OM) was determined using dichromate wet oxidation method as modified and described by Nelson and Sommers (1996). Exchangeable sodium percentage (ESP) of the soil was calculated using Mohsen *et al.* (2009) formula as follows: $ESP\ = \frac{Exchangeable\ sodiun}{CEC} \times 100$. Calcium carbonate content was determined using Collin's calcimeter method (Jackson, 1973). Water samples were collected during the agricultural season, filtrated using filter paper (No. 40) and subjected to chemical analysis according to the methods described by Jackson (1973).

Plant analysis

The maize plants were harvested after maturity stage (120 days) and determined of 100-grain weight (g); grain yield was determined for each plot then converted to kg fed^{-1}. The N, P and K in grains samples of maize crops were determined according to procedures described by Cottenie *et al.* (1982). Grain protein concentration was then determined using the formula: Protein concentration= % N × 6.25 (Amanullah and Shah, 2010). Irrigation water analysis was given in Table 1. The statistical analysis was analyzed by Statistical Package for Social Science (SPSS) version 20. Values were presented as mean. Statistical Differences between treatments were performed using one way ANOVA, the mean difference was significance at ($P \leq 0.05$) level according to Levesque (2007).

Table 1. Analysis of irrigation water

pH	EC	Cations $mmol_c\ l^{-1}$				Anions $mmol_c\ l^{-1}$				SAR	RSC	Potential
	$dS.m^{-1}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$			salinity
7.53	1.43	3.20	1.80	8.70	0.49	0.00	5.60	7.20	1.39	5.51	0.80	7.90

Results

Morphological properties of the studied soil profiles

Profile 1 is described as follows: layer 0-30 is brown (10YR 4/3, moist) to dark yellowish brown (10YR4/6, dry); loamy sand; single grains; friable; few fine roots; weak effervescence with HCl; clear smooth boundary. Layer 30-60 is yellowish brown (10YR5/4, moist) to yellowish brown (10 YR5/4, dry); sand; single grains; very friable; weak effervescence with HCl. Finally, layer 60-90 is yellowish brown (10YR5/4, moist) to yellowish brown (10 YR5/4, dry); sand; single grains; very friable; weak effervescence with HCl.

Profile 2 is described as follows: layer 0-30 is brownish yellow (10YR 6/5, moist) to dark light gray (10YR7/2, dry); loamy sand; single grains; very friable; very few fine roots; moderate effervescence with HCl; clear smooth boundary. Layer 30-60 is light gray (10YR7/2, moist) to very pale brown (10 YR7/3, dry); loamy sand; single grains; very friable; weak effervescence with HCl; clear smooth boundary. Finally, layer 60-85 is dark gray (10YR4/1, moist) to dark yellowish brown (10 YR4/4, dry); loamy; single grains; friable; moderate effervescence with HCl.

Profile 3 is described as follows: layer 0-20 is very dark grayish brown (10YR 3/2, moist) to dark gray brown (10YR4/2, dry); sandy loam; single grains; friable; few fine roots; weak effervescence with HCl; clear smooth boundary. Layer 20-40 is yellow (10YR7/6, moist) to white (10 YR8/1, dry); sand; single grain; very friable; weak effervescence with HCl; clear smooth boundary. Finally, layer 40-60 is gray brown (10YR5/2, moist) to light brownish gray (10 YR6/2, dry); sand; single grains; friable; moderate effervescence with HCl.

Profile 4 is described as follows: layer 0-20 is brownish yellowish (10YR 6/6, moist) to very pale brown (10YR7/3, dry); loamy sand; single grains; friable; few fine roots; weak effervescence with HCl; clear smooth boundary. Layer 20-40 is brown (10YR4/3, moist) to yellowish brown (10 YR5/4, dry); loamy sand; massive; friable; weak effervescence with HCl; clear smooth boundary. Finally, layer 40-65 is yellowish (10YR7/6, moist) to very pale brown (10 YR8/2, dry); sand; single grains; loose; moderate effervescence with HCl.

Chemical properties of the studied sites

Soil pH values of the studied soil samples is presented in Table 2. The values are fluctuating between 7.02 to 7.71 in the successive layers of the studied soil profiles.

Soil salinity expressed as EC is shown in Table 2 and illustrated in Figures 1 and 2. Generally, it could be noticed that the values decreased with depth. EC values ranged between 1.27 and 5.30 dSm^{-1} in the successive layers of the studied soil profiles. The data of cation exchange capacity (CEC) was related to organic matter and clay content. The values were ranged between 0.20- 0.84 % for OM and 3.80 to 8 $cmol_c\ kg^{-1}$ for CEC in the collected samples of the studied soil profiles. On the other hand, it was noticed that there were difference vertical distributions of $CaCO_3$ within the studied soil samples. The values ranged between 1.21 to 2.81% in the successive layers of the studied soil profiles.

As shown in Table 2 and illustrated in Figures 1 and 2 it can be noticed that, ESP increased with depth in profile 1 and 2, while it took the opposite trend in profile 3 and 4. Generally, the values were ranged between 7.5 to 14.16%.

Table 2. Soil chemical characteristics of the studied sites

Parameters	Non- saline soil (WTD≤ 90 cm)						Saline soil (WTD≤ 65cm)					
	Profile 1 Depth cm			Profile 2 Depth cm			Profile 3 Depth cm			Profile 4 Depth cm		
	0-30	30-60	60-90	0-30	30-60	60-85	0-20	20-40	40-60	0-20	20-40	40-65
pH (1:2.5 soil suspension)	7.71	7.02	7.00	7.58	7.55	7.53	7.70	7.10	7.13	7.80	7.83	7.70
EC dS.m^{-1} (1:2.5 soil extract)	1.62	1.42	1.27	2.40	1.75	1.50	5.30	4.22	4.40	4.92	4.12	4.00
OM %	0.64	0.55	0.50	0.42	0.35	0.28	0.38	0.25	0.20	0.82	0.80	0.42
CEC cmolc kg^{-1}	8.00	6.20	5.00	5.80	5.50	6.00	5.50	4.50	4.00	5.40	4.60	3.80
$CaCO_3$ %	1.45	1.37	1.21	2.81	1.41	1.30	2.21	2.01	2.77	1.80	1.41	1.33
Field capacity %	14.50	14.00	14.00	14.00	13.80	14.00	14.00	13.50	13.50	13.00	13.00	13.20
Ex. Na cmolc kg^{-1}	0.60	0.55	0.60	0.80	0.70	0.90	0.75	0.60	0.50	0.60	0.50	0.50
ESP %	7.50	8.87	12.00	13.79	12.72	14.16	13.63	13.33	12.50	11.11	10.87	13.16
Classification*	**Values**						**Values**					
pH	< 8.50						< 8.50					
EC	< 4						> 4					
ESP	< 15						< 15					

*Classification of salt affected soil according to Richards (1954)

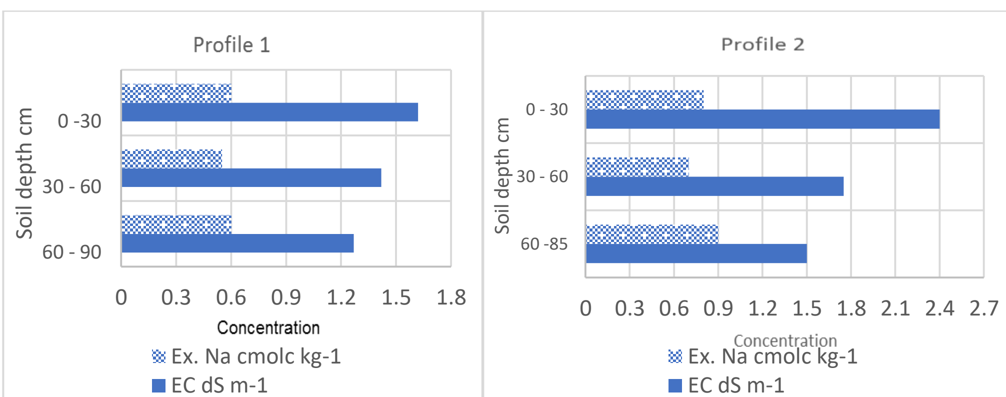

Figure 1. Distribution of soil salinity (dSm^{-1}) and exchangeable sodium (Ex. Na cmol$_c$ kg^{-1}) at non-saline soil (profile 1 and 2)

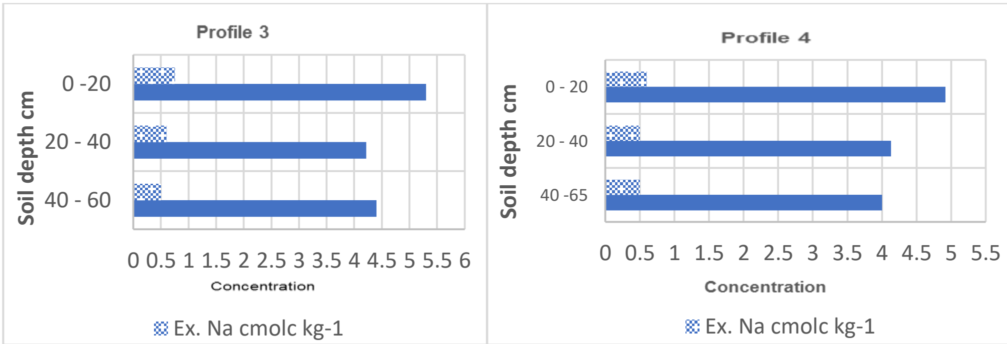

Figure 2. Distribution of soil salinity (dSm^{-1}) and exchangeable sodium (Ex. Na cmol$_c$ kg^{-1}) at saline soil (profile 3 and 4)

Physical characteristics of the studied sites

Soil particle size distribution is widely used in soil classification, as well as its association with soil properties. The size particle distribution was affected by depth, the fine particles in the surface layers were more than in the sub surface layers (Table 3). Generally, the dominant texture in the studied soil fluctuates between sandy loam to loamy sand. On the other side, the field capacity (FC) percentage increased by increasing the clay content. The values ranged between 13 to 14.5% in the studied samples. Also, the values of saturated hydraulic conductivity are associated by soil bulk density and the total porosity. It was noticed that hydraulic conductivity (*Ksat*) decreased with depth and increasing soil salinity for all soil samples. The values ranged between 4.20-5.20 cm.h^{-1} in non-saline soil and 7.50-6.20 cm.h^{-1}in saline soil. Also, there was a variation in the values of bulk density and total porosity in saline soil compared with non-saline. The values of Bd were ranged between 1.55 to 1.65 Mg m^{-3} in the successive layers of non- saline soil. While, the ranged values were between 1.58 to 1.70 Mg m^{-3} in saline soil. Also, the values of Bd were affected by OM and sand fractions.

Characteristics of ground water before planting and water table depth of the studied profiles during the agriculture period

The characteristics of water table i.e., pH, EC and total N were recorded (Table 4). In non-saline soil, the pH values were 7.66 and 7.73 in the water samples collected from profile 1 and 2, respectively. Moreover, EC values were 5.80 and 6.95 dSm^{-1} in profile 1 and 2, respectively. Also, total N was 25.5 and 43.80 mg. l^{-1}. On the other hand, in saline soil, the values of pH, EC and total N in profile 3 and 4 were 8.30 and 7.64; 9.80 and 7.40 $dS.m^{-1}$ and 56.40 and 45.50 mg. l^{-1}, respectively. Interestingly, it was noticed that the N losses were related by hydraulic conductivity.

Table 3. Physical characteristics of the studied sites

Parameters	Non- saline soil WTD ≤ 90 cm						Saline soil WTD ≤ 65cm					
	Profile 1 Depth cm			Profile 2 Depth cm			Profile 3 Depth cm			Profile 4 Depth cm		
	0-30	30-60	60-90	0-30	30-60	60-85	0-20	20-40	40-60	0-20	20-40	40-65
Bd $Mg.m^{-3}$	1.55	1.63	1.65	1.61	1.65	1.65	1.57	1.62	1.70	1.50	1.58	1.65
HC $cm.h^{-1}$	4.50	5.20	4.65	4.65	4.20	4.90	7.45	6.80	6.50	7.50	6.20	6.48
Field capacity %	14.50	14.00	14.00	14.00	13.80	14.00	14.00	13.50	13.50	13.00	13.00	13.20
Total porosity (%)	41.51	38.49	37.74	39.25	37.74	37.74	40.75	38.87	35.85	43.40	40.38	37.74
Sand %	63.50	68.00	78.00	65.50	70.75	73.55	75.80	78.40	80.70	68.55	70.50	73.40
Silt %	22.50	24.50	14.65	22.50	17.50	13.45	14.50	13.50	11.80	22.85	21.50	14.50
Clay %	14.00	7.50	7.35	12.00	11.72	13.00	9.70	8.10	7.50	8.60	8.00	12.10
Texture class	Sandy loam	Sandy loam	Loamy sand	Sandy loam	Sandy loam	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Sandy loam	Loamy sand	Loamy sand

Table 4. Some characteristics of ground water in the studied profiles before planting

Parameters	**WTD≤ 90 cm**		**WTD≤ 65 cm**	
	Profile 1	Profile 2	Profile 3	Profile 4
pH	7.66	7.73	8.30	7.64
EC dSm^{-1}	5.80	6.95	9.80	7.40
N $mg.kg^{-1}$	25.50	43.80	56.40	45.50

With regards to the water table depth was affected by agricultural practices. It illustrated that the values ranged between 83 cm to 50 cm in the agriculture period of maize crop (Figure 3).

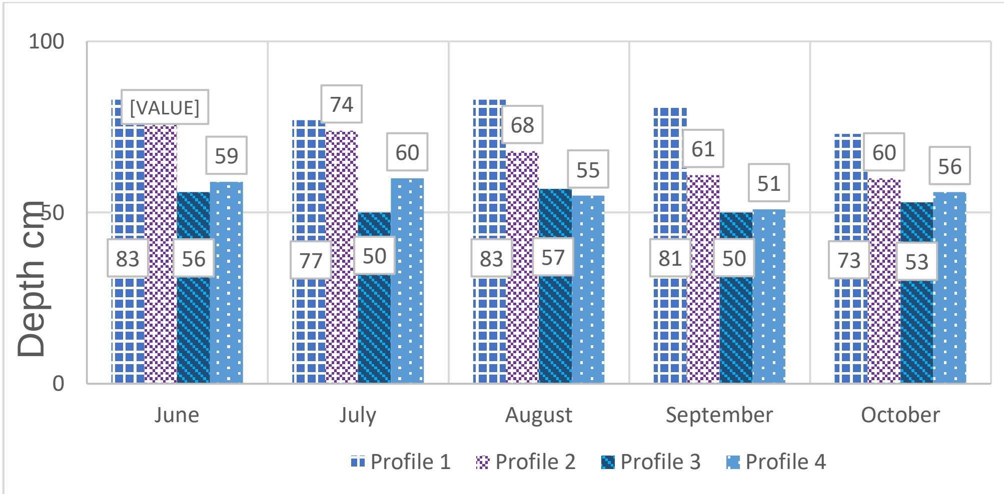

Figure 3. Monthly water table depth during agriculture period for maize crop

The maize's yield and chemical composition for grains as affected by soil salinity and WTD

The combined effect of water table depth and soil salinity on maize's yield and chemical composition of grains are shown in Table 5. Water table depth (≤65cm) in saline soil reduced grain yield and chemical composition of maize, as compared to WTD (≤90cm) in non-saline soil. Macronutrients (N P and K) content and crude protein were decreased with increasing salinity water table depth and soil salinity. On the other hand, foliar application of potassium silicate gave a significant increase in the chemical composition of maize grains. The values on NP and K for grains of maize grown in non-saline soil (site 1) were increased significantly ($p \leq 0.05$) by application of potassium silicate. NP and K vales were ranged between 1.63-2.11,0.25-0.32 and 1.35-1.63 %, respectively. Also, 4% potassium silicate gave a significant increase in the values of NP and K for grains of maize grown in non-saline soil (site 2). NP and K vales were ranged between 1.50-1.90,0.22-0.30 and 1.22-1.39 %, respectively.

While, the values on NP and K for grains of maize grown in saline soil (site 3) were increased significantly ($p \leq 0.05$) by application of potassium silicate. NP and K vales were ranged between 1.25-1.54,0.20-0.26 and 1.10-1.32 %, respectively. Also, in site 4 the values of NP and K were ranged between 1.30-1.55,0.20-0.25 and 1.20-1.345%, respectively.

Table 5. The maize's yield (kg.fed^{-1}), chemical composition of grains as affected by soil salinity and water table under application rates of potassium silicate

Parameters	**Non- saline soil WTD≤ 90 cm**						**Saline soil WTD≤ 65cm**					
	Site 1			Site 2			Site 3			Site 4		
	Potassium silicate %			Potassium silicate %			Potassium silicate %			Potassium silicate %		
	0	2	4	0	2	4	0	2	4	0	2	4
N%	1.63^{bc}	1.80^{b}	2.11^{a}	1.50^{b}	1.73^{ab}	1.90^{a}	1.25^{b}	1.35^{ab}	1.54^{a}	1.30^{bc}	1.40^{b}	1.55^{a}
Crude protein %	10.19	11.25	13.19	9.38	10.81	11.88	7.81	8.44	9.63	8.13	8.75	9.69
P%	0.25^{b}	0.30^{a}	0.32^{a}	0.22^{bc}	0.25^{b}	0.30^{a}	0.20^{b}	0.24^{a}	0.26^{a}	0.20^{b}	0.24^{a}	0.25^{a}
K%	1.35^{bc}	1.45^{b}	1.63^{a}	1.22^{b}	1.31^{ab}	1.39^{a}	1.10^{b}	1.22^{ab}	1.32^{a}	1.20^{c}	1.32^{b}	1.45^{a}
100 grain weight g	25.52^{bc}	28.5^{b}	31.00^{a}	20.5^{c}	23.5^{b}	26.60^{a}	20.0^{c}	24.3^{b}	27.54^{a}	22.5^{c}	25.3^{b}	27.0^{a}
Yield kg.fed^{-1}	2150^{c}	2233^{b}	2313^{a}	2040^{c}	2100^{b}	2155^{a}	2025^{c}	2130^{b}	2225^{a}	2033^{c}	2155^{b}	2211^{a}

There is no significant difference between means have the same alphabetical superscript letter in the same column ($p \leq 0.05$). The treatments in each site were compared with each other.

Meanwhile, the maize's yield increased significantly ($p \leq 0.05$) with increasing the application rates of potassium silicate. The highest values were recorded 2313, 2155,2225 and 2211 kg.fed^{-1} at sites 1, 2, 3 and 4 respectively under 4% foliar application of potassium silicate.

Discussion

Response of *Zea mays* to foliar application of potassium silicate under different levels of soil salinity and water table was studied. From the abovementioned results, based on pH, soil salinity, and exchangeable sodium percentage (ESP), soils represented with profile 1 and 2 were classified as none saline soil; while, the soil represented with profile 2 and 4 classified as saline soil (Richards, 1954). Salinity concerns are caused by the water table, salt content, fluctuations, and hydraulic conductivity; the impact was connected with the depth of the shallow water table compared to the level of the deep-water table, and with saline soils compared to non-saline soils. These data are in agreement with obtained by Abd El-Mageed *et al.* (2018). Almost soil pH increases by soil depth as a result of decreasing in organic matter. This trend is in agreement with those obtained by Mohamed (2002). Hydraulic conductivity, on the other hand, declined with depth for all soil samples. This could be due to subsurface layer compaction, which results in the reduction and discontinuity of big pores and, as a result, a decrease in hydraulic conductivity. Also, soil salinity, organic matter and CEC decreased with depth. Salinity has been shown to be a key environmental stress, with the ability to affect the carbon sequestration (Lucas and Carter, 2013). It was also noticed that the surface layer contains the high soluble salts. This is may be due to the movement of saline solution and its evaporation at soil surface. Ghosh *et al.* (2016) showed that, salts are transported by capillary rise due to evaporation from salts laden water table which rises that closely to the surface layers. When the water table rises closely to the soil surface, the net rate of water movement by capillary rise to the surface may exceed the water flow downwards, therefore, salts are transferred to the surface when the water evaporated and salts accumulated. The depth of the water table influences the dispersion of solutes through the unsaturated zone (Shokri-kuehni *et al.,* 2020). In addition, soil particle size distribution is of great importance for movement of soil water and migration of soil solute. It was, therefore, considered a crucial soil physical parameter and commonly used to predict soil hydraulic and other related parameters (Cornelis *et al.,* 2001). Some changes in particle size distribution may be useful indications of certain human activities (Liu *et al.,* 2009). Values of saturated hydraulic conductivity is associated by soil bulk density and the total porosity. The obtained trends were in agreement with those obtained of Jury *et al.* (1991), who discovered that increasing soil salt levels result in a considerable increase in hydraulic conductivity values. Saturated hydraulic conductivity values increased somewhat as water table depth decreased. This is attributed to improved soil structure in deep water table depths compared to high-water table depths (Abd El-Mageed *et al.,* 2018). It could be noticed that hydraulic conductivity is related to bulk density. Its known that bulk density is related to the proportions of solid and pore- space of the soil. In this concern, Horn and Smucker (2005) reported that the increase in bulk density implies a decrease in coarse pores and an increase in middle and fine pores which lead to change on hydraulic conductivity. The values in saline soil were higher than the values in non-saline soil. Such findings fall in line with those obtained by Jury *et al.* (1991). Also, bulk density was related by organic matter and soil texture. These findings are consistent with those of El-Sheihk (2003), who discovered that soil texture and organic matter (OM) influenced bulk density values. The differences in values of soil bulk density and hydraulic conductivity were affected by soil salinity and water table depth of the studied sites which observed. Huang *et al.* (2010) reported that the increasing in salinity of soils has influence on soil bulk density, and saturated hydraulic conductivity**.**

On the other side, foliar application of potassium silicate gave a positive effect on chemical composition of maize and its productivity. This due to that

Potassium silicate is a source of potassium and silicon, which lead to increase the quality of yield. Silicon has been documented to reduce multiple stresses in plants, including biotic and abiotic stresses, by maintaining water potential (Das *et al.,* 2017). Also, the yield was increased significantly by increasing the application rates of potassium silicate. Foliar application of silicon gave a significant increase in maize productivity (Hodge, 2019; Shedeed, 2018). While, soil salinity and water table gave negative effect on soil properties and productivity. The results were in accordance by Feng *et al.* (2017), who found that maize yield had a negative effect by increasing salinity. Also, increasing salinity and water table gave negative effect on macronutrients content in maize grain. This is may be due to the negative effect of salinity on plant growth and nutrients availability. The results showed that using the increased consecutive rates application of potassium silicate gave the highest significant values for macronutrients content in maize grain compared to control. These data are in agreement with those obtained by Shedeed (2018). Also**,** Bekmirzaev *et al.* (2020) reported that application of potassium can mitigate the negative effects of high salt levels in soil and also aids in the retention of plant water**.** The foliar application of potassium silicate had a considerable favorable effect on the protein content in mays grain. This is due to potassium's involvement in enhancing enzyme activity, which can be explained by the fact that potassium neutralizes numerous organic anions and other substances inside the plant, thereby aiding in the stabilization of the optimum pH for most enzymes (Ibrahim *et al.,* 2015). So, the results obtained that foliar application of potassium silicate especially at the highest application rate (4%) was improved the yield quality of grain yield.

Finally, it is concluded that the recognition of the relationship between crop productivity and water table depth are necessary known. It must be managed with an appropriate way. Indiscriminate use of agricultural practice was showed, especially irrigation water particularly in the areas of shallow or medium water table depth and low drainage system; leading to soil salinity. The obtained data cleared that there was negative effect of water table depth on soil properties. Therefore, under the conditions of this investigation. The findings prompted the need to maintain low levels of salinity and deep-water table depth is required or improve the soil properties to achieve the maximum yield of maize crop. On the other hand, foliar application of potassium silicate especially at the highest rate (4%) had a significant positive effect on macronutrients content and yield of maize plants as compared to control.

References

Abd El-Mageed, T. A., Mohammed, S. A., El-Samnoudi1, I. M. and Abd El-Aty, M. I. (2018). Interactive effects of soil salinity and water table depth on soil properties and sorghum (*Sorghum bicolor* L. Moench) production. Archives of Agriculture and Environmental Science, 3:15-24.

Abd El-Mageed, T. A. and Semida, W. M. (2015). Effect of deficit irrigation and growing seasons on plant water status, fruit yield and water use efficiency of squash under saline soil. Scientia Horticulture, 186:89-100.

Ahmad, A., Afzal, M., Ahmad, A. U. H. and Tahir, M. (2013). Foliar effect of silicon on yield and quality of rice. Cercetari Agronomice in Moldova, 3:21-28.

Ali, A., Basra, S. M., Iqbal, J., Hussain, S., Subhani, M. N., Sarwar, M. and Haji, A. (2012). Silicon mediated biochemical changes in wheat under salinized and non-salinized solution cultures. African Journal Biotechnology, 11:606-615.

Amanullah, K. and Shah, P. (2010). Timing and rate of nitrogen application influence grain quality and yield in maize planted at high and low densities. Journal of the Science of Food and Agriculture, 90:21-29.

Bekmirzaev, G., Ouddane B., Beltrao, J. and Fujii Y. (2020). The impact of salt concentration on the mineral nutrition of *Tetragonia tetragonioides*. Agriculture, 10:1-10.

Carpici, E. B., Celik, N., Bayram, G. and Asik, B. B. (2010). The effects of salt stress on the growth, biochemical parameter and mineral element content of some maize (*Zea mays* L.) cultivars. African Journal of Biotechnology, 9:6937-6942.

Chhabra, R. (2005). Classification of salt-affected soils. Arid Land Research and Management, 19:61-79.

Cornelis, W. M., Ronsyn, J. and Van Meirvenne, M. (2001). Evaluation of pedo transfer functions for predicting the soil moisture retention curve. Soil Science Society of America Journal, 65:638-648.

Corwin, D. L. (2020). Climate change impacts on soil salinity in agricultural areas**.** European Journal of Soil Science, 72:842-862.

Cottenie, A., Verloo, M., Velghe, G. and Comerlynk, R. (1982). Chemical analysis of plant and soil. Laboratory of analytical and Agro-Chemistry State University, Ghent, Belgium.

Das, K. K., Swamy, G. S., Biswas, D. and Chnaniya, K. K. (2017). Response of soil application of diatomaceous earth as a source of silicon on leaf nutrient status of guava. International Journal of Current Microbiology and Applied Sciences, 6:1394 -1399.

Dellavalle, N. B. (1992). Determination of soil-paste pH and conductivity of saturation extract. In Handbook on Reference Methods for Soil Analysis, pp.40-43. Soil and Plant Analysis Council, Inc. Athens, GA.

El- Sheihk, O. M. (2003). Salinity problems of soils irrigated with water of low qualities. (Ph. D. Thesis). Zagazig University, Egypt.

El-Nashar, Y. W. (2013). The combined effect of water-logging and salinity on crops yield. IOSR Journal of Agriculture and Veterinary Science, 4:40-49.

Feng, G. X., Zhang, Z. Y., Wan, C. Y., Lu, P. R. and Bakour, A. (2017). Effects of saline water irrigation on soil salinity and yield of summer maize (*Zea mays* L.) in subsurface drainage system. Agricultural Water Management, 193:205-213.

Gee, G. W. and Bauder, J. W. (1986). Particle size analysis. In: Klute, A. (Ed). Methods of Soil Analysis. Part 1: Agron Monogr. No. 9. 2nd ed, pp.383-411.

Ghosh, B., Ali, M. N. and Saikat, G. (2016). Response of rice under salinity stress: A review update. Journal of Rice Research, 4:167.

Grossman, R. B. and Reinsch, T. G. (2002). Bulk density and linear extensibility. In: Methods of Soil Analysis, Part 4, Physical Methods, Dane, J. H. and Topp, G. C. (eds.). ASA and SSSA, Madison, WI., USA, pp.201-228.

Hodge, M. (2019). Impact of a foliar applied silicate product on the observed and measured stalk strength of inbred Maize. Msc Thesis, Iowa State University Ames, Iowa.

Horn, R. and Smucker, A. (2005**).** Structure formation and its consequences for gas and water transport in unsaturated arable and forest soils. Soil & Tillage Research, 82:5-14.

Huang, C. H., Xue, X., Wang, T., Mascellis, R. D., Mele, G. and You Q. (2010). Effects of saline water irrigation on soil properties in northwest China. Environmental Earth Sciences, 63:701-708.

Ibrahim, M. F., Abd El – Gawad, H. G. and Bondok A. M. (2015). Physiological impacts of potassium citrate and folic acid on growth, yield and some viral diseases of potato plants. Middle East Journal of Agriculture Research, 4:577-589.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall Inc., USA.

Jalili, S., Moazed, H., Nasab, S. B. and Naseri, A. A. (2011). Assessment of evaporation and salt accumulation in bare soil: Constant shallow water table depth with saline ground water. Scientific Research and Essays, 6:6068-6074.

Jury, W. A., Gardner, W. R. and Gardner, W. H. (1991). Soil Physics. John Wiley & Sons, New York., U.S.A.

Kamai, T. and Assouline, S. (2018). Evaporation from deep aquifers in arid regions: Analytical model for combined liquid and vapor water fluxes. Water Resources Research, 54:4805-4822.

Levesque, R. (2007). SPSS programming and data management: A Guide for SPSS and SAS user .3rd edition USA.

Liang, Y. C., Zhu, J. and Li, Z. J. (2008). Role of silicon in enhancing resistance to freezing stress in two contrasting winter wheat cultivars. Environmental and Experimental Botany, 64:286-294.

Liu, X., Zhang, G. C., Heathman, G. C., Wang, Y. Q. and Huang, C. H. (2009). Fractal features of soil particle-size distribution as affected by plant communities in the forested region of Mountain Yimeng, China. Geoderma, 154:123-130.

Lucas, K. L. and Carter, G. A. (2013). Change in distribution and composition of vegetated habitats on Horn Island, Mississippi, northern Gulf of Mexico, in the initial five years following hurricane Katrina. Geomorphology, 199:129-137.

Mohamed, A. A. (2002). Water quality control in open drains and its effect on soil properties. (Ph.D. Thesis). Ain Shams University, Egypt.

Mohsen, S., Majid, R. and Borzoo, G. K. (2009). Prediction of soil exchangeable sodium percentage based on soil sodium adsorption ratio. American-Eurasian Journal of Agricultural & Environmental Sciences, 5:1-4.

Morrison, R. D. (1983). Ground Water Monitoring: Technology, Procedures Equipment's and Application. Inc. Wisconsin, U.S.A.

Nelson, D. W. and Sommers, L. E. (1996). Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America Book Series, 5:961-1010.

Richards, L. A. (1954). Saline and Alkali Soils: Diagnosis and Improvement. USDA Agriculture Research Service Handbook 60.

Salim, B. B. (2014). Effect of boron and silicon on alleviating salt stress in maize. Middle East Journal of Agriculture Research, 3:1196-1204.

Schwabe, K. A., Kan, I. and Knapp, K. C. (2006). Drain water management for salinity mitigation in irrigated agriculture. American Journal of Agricultural Economics, 88:133-149.

Semida, W. M., Abd El-Mageed, T. A., Sabry, E. M. and Nevein, A. E. (2017). Combined effect of deficit irrigation and foliar applied salicylic acid on physiological responses, yield, and water use efficiency of onion plants in saline calcareous soil. Archives of Agronomy and Soil Science, 63:1227-1239.

Shedeed, Sh. I. (2018). Assessing effect of potassium silicate consecutive application on forage maize plants (*Zea mays* L.). Journal of Innovations in Pharmaceutical and Biological Sciences, 5:119-127.

Shokri-kuehni, S., Raaijmakers, B., Kurz, T., Or, D., Helmig, R. and Shokri, N. (2020). Water table depth and soil salinization: from pore-scale processes to field-scale responses. Water Resources Research, 56:1-13.

Sumner, M. E. and Miller, W. P. (1996). Cation exchange capacity and exchange coefficients. Pages 1201-1229 in D. L. Sparks, A. L. Page, and P. A. Helmke, editors, Methods of Soil Analysis. Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin, USA.

Thomas, G. W. (1996). Soil pH and soil acidity. In D.L. Sparks (ed.) Methods of soil analysis. Part 3. Chemical methods. SSSA Book Ser. 5. SSSA, Madison, WI., pp.475-490.

Tsypkin, G. G. and Shargatov, V. A. (2018). Influence of capillary pressure gradient on connectivity of flow through a porous medium. International Journal of Heat and Mass Transfer, 127:1053-1063.

Wong, V. N. L., Greene, R. S. B., Murphy, B. W., Dalal, R. and Mann, S. (2005). Decomposition of added organic material in salt-affected soils. IN ROACH, I. C (Ed.) Cooperative Research Centre for Landscape Environments and Mineral Exploration Regional Regolith Symposia, 2nd-4th November. CRC LEME, Canberra.

Yoo, G., Kim, H., Chen, J. and Kim, Y. (2014). Effects of biochar addition on nitrogen leaching and soil structure following fertilizer application to rice paddy soil. Soil Science Society of America Journal, 78:852-860.

Youngs, E. G. (2001). Hydraulic conductivity of saturated soils. In; Soil and Environmental Analysis. Smith, K.A. and C.E. Mullins (Eds.). Physical Methods. 2nd Ed. Marcel Decker Inc. NY. pp.637.

Zvomuya, F., Rosen, C. J., Russelle, M. P. and Gupta, S. C. (2003). Nitrate leaching and nitrogen recovery following application of polyolefin-coated urea to potato. Journal of Environmental Quality, 32:480-489.

(Received: 6 March 2021, accepted: 18 June 2021)