Research Journal of Agricultural Biological Sciences, 2(6): 512-519, 2006

Effect of Potassium Rates on Barley Growth and its Mineral Content under Different Salt Affected Soil Conditions.

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Abstract: Pot experiment was conducted during 2003 season to study the response of barley plants (*Hordum vulgare* cv. Giza 123) to K - rates under conditions of saline, sodic and saline sodic soils. Rates of K were 0 (R_0), 12 (R_1), 24 (R_2) and 48 (R_3) mg K / kg soil (as K_2SO_4, 43 % K). The obtained results could be summarized as follows: K application significantly decreased germination rate and showed decrease of 10.48, 18.69 and 30.92 %, due to application of R_1, R_2 and R_3, respectively as compared with R_0. The effect of applied K on decreasing the germination rate under the tested soils followed this descending order: saline > saline sodic > sodic. Increasing K rates significantly increased germination percentage of barley seeds. This result showed that it could be useful to apply K fertilizer to barley plants to grow better under saline conditions. Increasing K rates (R_1, R_2 and R_3) progressively increased the yield of both straw and grains as well as plant height, No. of tillers and spikes of barley plants as compared with R_0 (control). The lowest values of both straw and grains yields as well as growth parameters of barley plants were obtained under the saline sodic soil condition followed by sodic and saline soils in increasing order. These results reflect the combined effect of salinity and sodicity in decreasing the growth parameters of barley plants as compared with saline or sodic effect each alone. Significant interaction was found between the used soils and K rates on N-uptake by barley straw and grains. The highest values of N-uptake by straw and grains were attained at R_3 (48 mg K/kg soil) under sodic soil, while the lowest ones were found at R_0 under saline soil. Under all different soils conditions and K rates, nitrogen uptake by barley grains was higher than their corresponding treatments of straw. Application of different K rates resulted in significant increases in P-uptake by straw and grains of barley plants. Moreover, this pattern of response occurred in all the investigated soils where each increase in K rate was accompanied with an increase in P-uptake by straw and grains of barley plants. The highest P-uptake by straw was found under saline sodic conditions, while the highest ones by grains were obtained under sodic conditions. Increasing K rates significantly and progressively increased K-uptake by straw and grains of barley plants. Barley plants grown on saline soil gave the highest values of K-uptake by straw and grains followed by plants grown on sodic and saline sodic soils in decreasing order. The highest values of Na-uptake by straw were obtained under saline conditions followed by sodic and saline sodic conditions in decreasing order, while Na-uptake by grains of barley plants was significantly higher under sodic soil as compared with those obtained under saline or saline sodic soil conditions. Progressively increases occurred in both Ca and Mg uptake by straw and grains of barley plants with increasing K rates. Generally, Ca and Mg uptake by starw and grains of barley plants grown on all the used soils, showed the same trend as affected by K rates under different soils. The highest levels of both Ca and Mg uptake by straw and grains were obtained under sodic soil followed by saline sodic and saline soils in decreasing order.

Key words: Saline, Sodic,Saline sodic soil, potassium rates, barley, growth parameters, mineral content.

INTRODUCTION

Salt affected soils occupy wide regions scattered all over the world (about 954 millions of hectares,[1], particularly in arid and semi-arid regions. Salt stress is one of the most serious limiting factors for crop growth and production in the arid regions. About 23 % of the world's cultivated lands is saline and 37 % is sodic[2]. Salinity can also affect plant growth because the high concentration of salts in the soil solution interferes with balanced absorption of essential nutritional ions by plants[3].

Fertilizer application under saline cultivations is now being tried to alleviate or neutralize growth inhibition due to salinity and to increase the productivity of the saline soils[4]. Fertilization with nutrients like K and Ca as cations and P or N as anions increase the ability of plants to take up sufficient K and Ca and/or P and N to avoid the accumulation of too much Na and Cl, respectively.

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Helal and Mengel[5] reported that salt stress on barley caused by NaCl could be reduced by an increase of K supply. Therefore, it is assumed that the application of potassium fertilizer to the needed level by the crop and preferably in the form of K_2SO_4 will improve plant tolerance to salinity. The same results have been reported by numerous workers on tomato plants with different fertilizers, e.g. Satti and Lopez [6] with KNO_3, Satti and Al-Yahyai [7] with K_2SO_4 and H_3PO_5 and Lopez and Satti[4] with KNO_3 and $Ca(NO_3)_2$.

Increasing the quantities of K in the nutrient solution did not limit the uptake and accumulation of sodium but resulted in excessive potassium uptake[8]. Also, potassium is considered a major osmotically active solute of plant cell [9] where it enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency [10].

Barley is considered one of the important cereal crops in Egypt and in arid regions which are poor and saline [11].

The present investigation aims to study the effect of applying K-fertilizer to salt affected soils (saline, sodic and saline sodic soils) on barley growth and its uptake of nutrients.

MATERIALS AND METHODS

A green-house pot experiment was conducted to study the effect of K application to salt affected soils on barley growth and its nutrients uptake. Three soils were collected for the present study from El-Kalubia, Al-Ismailia and El-Fayoum Governorates representing saline, sodic and saline sodic soils, respectively. The soils were air-dried, ground and passed through a 2-mm sieve. The soil portions were uniformly packed in plastic pots of 30-cm diameter and 30-cm height at a rate of 8 kg soil per pot.

Physical and chemical properties of the used soils are shown in table (1). Soil analysis were conducted by the standard methods described by Piper [12], Richard [13], Black [14] and Cottenie, *et al*[15].

The design of the experiment was randomized complete block factorial, including two factors in four replicates (3 soils X 4 K rates X 4 replications).

Barley (*Hordum vulgare* L.) cv. Giza 123 was sown at the 15th of November 2003. Rates of K were 0 (R_0), 12 (R_1), 24 (R_2) and 48 (R_3) mg K / kg soil (as K_2SO_4, 43 % K). All pots received 15 mg P/kg soil (as Ca-superphosphate, 15 % P_2O_5); and 45 mg N/kg soil (as NH_4NO_3, 33.5 % N). Application of fertilizer nutrients, i.e., K and P was done in a form of water solution added in the first irrigation. Nitrogen fertilizer was added in three equal doses, at 1st, 3rd and within the 5th irrigation, respectively. Irrigation intervals were 4 days to maintain the soil moisture content at the field capacity

Table 1: Physical and chemical properties of the investigated soils.

Parameters	Saline soil	Sodic soil	Saline sodic soil
	Particles size distribution		
Coarse sand %	12.2	60.5	9.4
Fine sand	18.8	17.7	10.5
Silt	37.8	6.7	40.7
Clay	31.2	15.1	39.4
Texture	Clay loam	Sandy loam	Clay loam
Water holding capacity %	31.7	20.2	34.45
pH (1:2.5 soil: water suspension)	6.8	8.4	7.2
EC, dSm^{-1} (soil extract)	11.5	2.7	14.8
Organic matter, %	2.1	1.7	1.5
$CaCO_3$, %	1.7	2.3	4.8
CEC (mol/kg soil)	52.3	15.6	37.2
ESP, %	13.6	60.4	43.2
	Soluble ions (meq/l) in soil paste extract		
$CO_3^{=}$	0.0	0.0	0.0
HCO_3^-	3.8	21.0	7.0
Cl^-	32.4	7.0	101.0
$SO_4^{=}$	45.2	1.0	42.0
Ca^{++}	39.6	2.0	38.2
Mg^{++}	30.6	1.0	23.1
Na^+	25.0	16.2	66.5
K^+	20.0	8.5	8.1
	Available nutrients (mg kg^{-1} soil)*		
N	67.7	80.0	2.4
P	4.9	12.3	3.7
K	392.0	70.0	257.0

*N: KCl extract, P: $NaHCO_3$, K: Ammonium acetate

of the used soils during plant growth. Germination rate, germination percentage (as calculated by Edmond and Drapala,[16], plant height, number of spikes and number of tillers were recorded.

Yield was harvested when the grains were rippned at 30th of April 2004. The grains were separated from the vegetative part and yields of both components were measured. The obtained straw and grains from each pot were analyzed separately for N, P, K, Na, Ca and Mg according to Cottenie *et al* [15] and Bremner and Mulvaney[17].

The obtained data were subjected to statistical analysis according to Gomez and Gomez[18].

RESULTS AND DISCUSSIONS

Effect of potassium application on germination, growth parameters and yield components of barley plants grown under conditions of saline, sodic and saline sodic soils:

It is well known that potassium is important in regulating transpiration and dry matter per unit supply in salinized plants. This may be due to potassium shortage under such conditions. Sodic soils are dominant by Na adversely affects K concentration of the plants [19].

Effect on seed germination: Seed germination is a major factor limiting the establishment of plants under saline conditions, since the germination process represents the first stage of plant growth in addition to its high sensitivity to nutritional and environmental conditions.

Table 2: Effect of K-fertilizer on seed germination, growth parameters and yield of barley plants grown on different salt affected soils (saline, sodic and saline sodic soils).

Treatment		Seed germination		Growth parameter			Yield, g/pot	
Soil	K rates*	rate	%	Plant height,cm	No. of tillers	No. of spikes	Straw	Grains
Saline	R_0	1.20	76.67	45.30	16.67	13.33	16.25	10.99
	R_1	1.03	88.33	46.33	16.68	16.33	16.66	12.55
	R_2	0.96	90.00	54.00	21.00	18.67	18.57	14.13
	R_3	0.74	98.33	58.00	22.00	19.67	21.01	15.17
	mean	0.98	88.33	50.16	19.09	17.00	18.12	13.21
Sodic	R_0	1.40	96.33	44.67	11.67	8.67	9.23	4.14
	R_1	1.28	96.67	45.67	14.33	11.60	11.77	8.22
	R_2	1.11	100.00	50.00	15.00	12.33	13.77	9.16
	R_3	1.09	100.00	53.62	18.00	13.67	16.22	9.53
	mean	1.22	98.25	48.49	14.75	11.57	12.75	7.77
Saline sodic	R_0	1.19	88.33	26.37	10.00	4.33	6.49	3.04
	R_1	1.14	98.33	31.67	10.00	6.00	7.14	3.70
	R_2	1.14	100.00	34.67	10.00	6.67	7.90	4.18
	R_3	1.08	100.00	47.00	10.00	7.00	8.86	5.42
	mean	1.14	96.67	34.93	10.00	6.00	7.60	4.09
Means of K rates	R_0	1.26	86.11	38.78	12.78	8.78	10.66	6.07
	R_1	1.15	94.44	41.22	13.67	11.31	11.86	8.16
	R_2	1.07	96.67	45.22	15.33	12.56	13.41	9.16
	R_3	0.97	99.44	52.87	16.67	13.45	15.36	10.04
Soils	LSD 5 %	0.12	6.67	7.62	1.78	1.24	0.49	0.62
	LSD 1%	0.16	9.05	10.35	2.452	1.73	0.67	0.84
K-rates	LSD 5 %	0.11	4.01	2.10	2.06	2.11	0.57	0.71
	LSD 1%	0.18	6.20	4.11	2.79	3.06	0.78	0.96
Intera ctions	LSD 5 %	NS	NS	NS	NS	2.55	0.97	1.23
	LSD 1%	NS	NS	NS	NS	3.46	1.34	1.68

* K rates: R_0: 0 mg K/kg soil; R_1: 12 mg K/kg soil; R_2: 24 mg K/kg soil and R_3: 48 mg K/kg soil

Data in table (2) show the effect of different rates of K-fertilizer on germination rates as well as germination percentage of barley seeds sown under conditions of saline, sodic and saline sodic soils. Results show that K application caused significant decrease in germination rate. The decreases were progressive with increasing K rate. The main effect of K application showed decreases of 10.34, 18.96 and 30.92 % due to application of R_1, R_2 and R_3, respectively as compared with R_0. This confirms the importance of K-fertilizer application under salinity and sodicity conditions to accelerate seedling emergence of the plant. The decrease in germination rate with increasing K rates may be due to K-fertilizer alleviates the hazardous effect of salinity and sodicity on barley seed germination and hence decrease the number of days required for germination.

The decrease in germination rate was more pronounced in plant grown on saline and saline sodic soils than those grown on the sodic one especially at the highest rate of K (R_3, 48 mg K/kg soil). The obtained results indicate that sodicity has a more hazardous effect on germination rate of barley seeds than salinity alone or salinity and sodicity together.

Comparing results of the used soils, data in Table (2) show that the highest values of germination rate were obtained under the sodic soil conditions followed by saline sodic and saline soil conditions in decreasing order. The effect of applied K on decreasing the germination rate of barley seeds under the three soil could be arranged as follows: saline > saline sodic > sodic. Data also show that there was non significant interaction between soils and K application on germination rate.

Data presented in Table (2) show increasing K rates from 0 to 48 mg K /kg soil resulted in significant increases in germination percentage of barley seeds. These increases were 8.33, 10.56 and 13.33 % for R_1, R_2 and R_3, respectively as compared with R_0. These results are in good agreement with those obtained by Sherif *et al.* [20] who found that the addition of K increased the germination percentage of wheat plants. The highest germination percentage was obtained under sodic soil conditions followed by saline sodic and saline soil conditions in decreasing order. The germination percentages under sodic soil and saline sodic conditions were significantly higher as compared with those obtained under saline conditions, however, there were non-significantly differences between sodic and saline sodic soils in germination percentage.

Data also show that the interaction between the used soils and K rates did not show any significant effect on germination percentage. However, the highest rates of K-fertilizer ($R_2$and R_3) gave the highest values of germination percentage under sodic and saline sodic conditions, while the lowest values were attained by control treatment (R_0) under saline soil conditions. These results show that it could be useful to apply K-fertilizer to barley plants to grow better under saline conditions. In this concern, Noufal [21] and Al-Karaki[22] reported that there was an adverse effect of salinity on barley seed germination in sandy and alluvial clayey salinized soils and this effect depends on soil texture. They added that increasing total salinity concentration decreased germination percentage, but increased the germination rate of sorghum, beans, tomatoes, barley and cotton seeds. They also revealed that the adverse effects of salt stress on seed germination is to a great extent due to osmotic reasons more than to a specific ion toxicity effects.

Effect on growth parameters: Data presented in Table (2) show the effect of K rates on growth parameters, i.e. plant height, No. of tillers and spikes of barley plants grown on saline, sodic and saline sodic soil conditions. Results revealed that increasing K rate from 0 to 48 mg K /kg soil (R_0 to R_3) significantly and progressively increased height of barley shoots. The main effect of K rates showed increases of about 6.32, 16.92 and 36.42 % at R_1, R_2 and R_3, respectively.

Comparing the plant height, data show that the highest values of plant heights were obtained under the conditions of the saline soil followed by sodic and saline sodic soils in decreasing order. Moreover, plant height values of barley under saline and sodic soil conditions were significantly higher than those obtained under saline sodic conditions. However, there were non-significant differences between plant height under saline and sodic soils. Also, data show that plant heights of barley grown on saline and sodic soils were 1.44 and 1.39 times when compared with those obtained from saline sodic soil, respectively.

The interaction between soils and K rates did not show any significant effect on plant height. However, the highest plant heights were obtained at R_3 under saline soil conditions, while the lowest ones were found at R_0 under saline sodic soil conditions.

Results present in Table (2) show that K rates significantly increased the number of tillers of barley plants. The increases were significantly progressive with the increases of K rates. The main effect of K rates showed increases in tillers number of 22.25, 27.75 and 38.92 % by using K rates of R_1, R_2 and R_3, respectively as compared with R_0. The differences in tillers No. as affected with different soils were highly significant. Comparison between the used soils, data show that the highest numbers of tillers were obtained when barley plants grown on saline soil followed by sodic and saline sodic soils in decreasing order. The interaction between the soils under investigation and K rates did not show any significantly effect. However, the highest numbers of tillers were obtained at R_3 under saline soil conditions and the lowest ones were found under saline sodic soil conditions.

Results presented in Table (2) show that K rates (R_1, R_2 and R_3) significantly increased the number of plant spikes, as compared with R_0 treatment, however, this effect did not reach the level of significance at the probability level of 5 % between a R_2 and R_3. The main values of increases due to K rates were 28.96, 43.22 and 53.36 % at R_1, R_2 and R_3, respectively, when compared with control (R_0). Data also, show significant differences in spikes number of barley plants among used soils. The highest values of spikes number was obtained when plants were grown under saline soil conditions followed by sodic and saline sodic soil conditions in decreasing order. The obtained values of spikes number under saline and sodic soils condition were 2.92 and 1.89 times, respectively, as compared with that obtained under saline sodic soil conditions.

The interaction between the used soils and K rates significantly affected the spikes number of barley plants (Table 2). Significant differences in number of spikes were noticed where the rates of R_1, R_2 and R_3 compared with the control of saline and sodic soils. Under saline sodic soil significant difference was noticed only between the control and treatment received R_3. Data also show that the highest values of spikes number were obtained with using K rate of 48 mg K /kg soil (R_3) under the saline soil conditions. Moreover, the lowest values of spikes number were obtained under R_0 (control) in saline sodic soil conditions.

Effect on yield of barley plants: Data in Table (2) show the effects of different K rates on straw and grain yields of barley plants grown on saline, sodic and saline sodic soils. Results show that different rates of K (R_1, R_2 and R_3) significantly increased the straw yield of barley plants as compared with the control treatment (R_0). The main effect of K rates showed increases of 11.3, 25.8 and 44.1 % at R_1, R_2 and R_3, respectively as compared with R_0 treatment.

Comparison between data of the three soils show that the highest straw yield was obtained in plants grown on the saline soil followed by those grown on sodic and saline sodic soils in decreasing order. The straw yield obtained under the saline and sodic soil conditions were 2.38 and 1.68 times, respectively as compared with that obtained under saline sodic soil conditions.

Data in Table (2) also show that the interaction between soils and rates of K-fertilizer significantly affected straw yield of barley plants. The increase in yield which was associated with increasing K rate differed from soil to soil as a result of significant interaction between soils and K rates. The highest straw yield values were obtained by using potassium at a rate of R_3 under saline soil conditions, while the lowest ones were obtained by using different rates of K (R_1, R_2 and R_3) under saline sodic soil conditions. These results indicate that application of K at high rate has simulative effect on barley tolerance to salinity combined with sodicity.

Concerning grain yield, data in Table (2) show that barley grain yield significantly increased by increasing the rate of K-fertilizer from 0 (R_0) to 48 mg K /kg soil (R_3). The main effect of K rates showed increases by 34.43, 50.90 and 65.40 % at R_1, R_2 and R_3, respectively as compared with R_0 (control).

Comparison among the three soils showed that the highest grain yield of barley was obtained under conditions of the saline soil followed by sodic and saline sodic soil in descending order. Grains yield obtained under the saline and the sodic soil conditions were 3.26 and 1.90 times, respectively as compared with that obtained under the saline sodic soil conditions.

Data in Table (2) also show that the interaction between soils and K rates revealed significant effect on grain yield of barley plants. The highest grain yield was obtained by using the potassium rate of 48 mg K/kg soil (R_3) under the saline soil conditions, while the lowest one was obtained under control treatment (R_0) and the saline sodic soil conditions. Generally, the grain yield of barley plants grown on the different soils treated with same K rates, took the same trend of the straw yield.

Table 3: Effect of K-fertilizer on N, P and K uptake (mg/pot) by straw and grains of barley plants grown on different salt affected soils (saline, sodic and saline sodic soils).

Treatment		Uptake of N, P and K (mg/pot)					
		N		P		K	
Soil	K rates*	Straw	Grains	Straw	Grains	Straw	Grains
Saline	R_0	63.33	133.33	44.67	39.67	812.00	95.50
	R_1	86.67	170.00	81.00	63.67	815.00	112.50
	R_2	116.67	246.67	88.67	66.67	1036.00	113.90
	R_3	223.33	396.67	135.33	74.33	1065.01	131.00
	mean	122.50	236.67	87.42	61.09	932.00	113.30
Sodic	R_0	136.11	173.33	53.67	162.33	402.00	39.13
	R_1	160.00	435.00	70.00	204.33	661.00	81.90
	R_2	166.67	750.00	123.33	253.33	765.00	86.80
	R_3	256.67	820.00	128.00	287.67	773.00	88.70
	mean	179.86	544.58	93.75	226.92	650.00	74.20
Saline sodic	R_0	70.00	430.00	66.67	93.00	95.20	32.90
	R_1	96.67	426.67	72.33	141.33	183.00	42.10
	R_2	103.33	563.33	256.67	146.67	211.00	53.30
	R_3	153.33	663.33	295.00	188.67	248.00	62.10
	mean	105.83	520.83	172.67	142.42	193.00	47.60
Means of K rates	R_0	89.81	245.35	55.00	98.33	436.00	56.00
	R_1	114.45	343.89	74.44	136.45	553.00	78.80
	R_2	128.67	520.00	156.00	155.56	671.00	84.70
	R_3	211.11	626.67	186.11	183.57	707.00	93.90
Soils	LSD 5 %	35..69	59.64	41.74	36.34	72.00	0.48
	LSD 1%	48.51	81.06	56.73	49.40	98.00	0.65
K-rates	LSD 5 %	20.11	68.87	19.01	25.71	83.00	0.55
	LSD 1%	36.11	93.70	35.16	47.12	113.00	0.75
Interactions	LSD 5 %	30.11	51.31	38.11	32.22	NS	0.96
	LSD 1%	40.22	70.75	50.19	43.68	NS	1.30

* K rates: R_0: 0 mg K/kg soil; R_1: 12 mg K/kg soil; R_2: 24 mg K/kg soil and R_3: 48 mg K/kg soil

The lowest yield of both straw and grains as well as plant height, No. of tillers and No. of spikes were obtained under the saline sodic soil conditions followed by sodic and saline soil in increasing order. These results reflect the combined effect of salinity and sodicity in decreasing the growth parameters and yields of barley plants as compared with saline or sodic effect alone. The amount of soluble salts in the saline sodic soils at root zone increases its osmotic pressure and hence the availability of water to plants is decreased and the growing plants suffer from water deficiency which resulted in a substantial reduction in yield. As with removal of water from the soil by (transpiration or by evaporation) salt concentration in the root zone would rise and concentration of specific ions would build up. Growth depression attributable to osmotic potential is called an osmotic effect, while that which is due to high concentration of some specific ions is called a specific ion effect. Confirm the previous hypothesis Oertil [23], Oster *et al.* [24] and Mozafar and Oertil [25].

Generally, addition of K-fertilizer improved the growth of barely plants grown on salt affected soil and gave a beneficial effect on the grain yield. Similar results were found by Shalaby *et al.* [26] and Sherif *et al.* [20].

Effect of potassium application on nutrients uptake by barley plants grown under conditions of saline, sodic and saline sodic soils:

Effect on nitrogen uptake: Data presented in Table (3) reveal that regardless the effect of the used soils, increasing potassium rate from 0 to 48 mg K/kg soil (R_0 to R_3) progressively and significantly increased nitrogen uptake by straw and grains of barley plants. However, the increases did not reach the level of significance at 5% when R_2 compared with R_1 in straw. The main effect of K rates on straw showed increases of 27.44, 43.27 and 13.51%, while the corresponding increases were 40.05, 111.77 and 155.20 % in grains at R_1, R_2 and R_3, respectively as compared with R_0. Data also reveal that the highest values of N-uptake by straw were obtained under sodic soil conditions followed by saline and saline sodic soils in decreasing order. Moreover, nitrogen uptake by straw under sodic soil conditions was significantly higher than those obtained under saline and saline sodic soil conditions. Nitrogen uptake by barley straw under sodic soil conditions was 1.47 and 1.70 times as compared with those obtained under saline and saline sodic soil conditions, respectively.

Concerning nitrogen uptake by grains, data in Table (3) show that the highest values were obtained under sodic soil followed by saline sodic and saline soil conditions in descending order. Nitrogen uptake under sodic and saline sodic soil conditions was significantly higher than those obtained under saline soil conditions.

Moreover, there were no significant differences in N-uptake by grains between sodic and saline sodic soils. Nitrogen uptake by grains under sodic soil conditions was 2.3 and 1.05 times as compared with those obtained under saline and saline sodic conditions, respectively.

Under all the different soil conditions and K rates, values of nitrogen uptake by barley grains were higher than their corresponding ones of straw. Similar results were reported by El-Sayed *et al.* [27].

Data in table (3) show significant interaction between the used soils and K rates on nitrogen uptake by barley straw and grains. The highest values of N-uptake by straw were obtained at rate R_3 under sodic soil conditions, while the lowest ones were found at R_0 under saline soil conditions. The significancy of the interaction may be due to change in the proportion of the increase resulted from increasing K rate among soils. Concerning N-uptake by grains, the highest values were obtained at R_3 under sodic soil conditions and the lowest values were found at R_0 under saline soil conditions. In the case of grains, the significancy of interaction may be due to the different behaviors of soils when treated with K and sodic soil revealed a superiority over all tested soils. Data, also reveal that under all the used soils, each increase in k rate was accompanied with an associated significant increase in N-uptake by grains. Similar results were obtained by Shehata and Farrag[28].

Effect on phosphorous uptake: Regardless of the soils effect, data in Table (3) show that application of K-rates resulted in significant increases in P-uptake by straw and grains. These increases were significantly progressive with increasing of K-rates up to the highest rate of R_3.

However, the increase in P-uptake by grains did not reach the level of significance at 5% when R_1 treatment compared with R_2 treatment. The main effect of K application showed increases in P-uptake of 35.35, 183.64 and 238.38 % by straw and 38.76, 58.20 and 86.60 % by grains at R_1, R_2 and R_3, respectively as compared with R_0. However, this pattern of response occurred particularly in all soils under investigation where each increase in K application was accompanied with an associated increase in P-uptake by straw and grains of barley plants. Therefore, K application was more pronounced in its effect in the investigated soils.

Data in Table (3) reveal that the different soils significantly affect P-uptake by straw and grains of barley plants grown therein. The highest P-uptake by straw was obtained under saline sodic conditions followed by sodic and saline soils in decreasing order, while the highest values of P-uptake by grains were found under sodic conditions followed by saline sodic and saline soils in decreasing order. Phosphorous uptake by straw under saline sodic conditions was significantly higher as compared with P-uptake under both sodic and saline soil conditions. However, P-uptake under saline conditions did not show any significant differences when compared with those obtained by plants grown on sodic soil. Moreover, data also, show that P-uptake by grains of plants grown on sodic soil was significantly higher as compared with those obtained under saline sodic and saline soils conditions. The increases in P-uptake of straw and grains of barley plants grown on the used soils may be attributed to increasing needs of plants to P for several biological and physiological activities as stated by Mass *et al*. [29]. The low P-uptake by plants under the conditions of saline soil, in particular, resulted in the low growth obtained under such conditions. Some researchers indicate that salinity may increased P requirement of a certain crop. Gunes *et al*. [30] reported that salinity increased the P-uptake of the plants and/or plants in saline medium were found to be more sensitive to P toxicity.

The data presented in Table (3) reveal that the interaction between soils and K rates had a significant effect on P-uptake by grains and straw of plants grown on the different soils. The highest values of P-uptake by straw were found at rate R_3 and under saline sodic soil conditions, while the lowest ones were obtained at R_0 under saline soil. Moreover, the highest values of P-uptake by grains were found at R_3 under sodic soil and the lowest values were attained at R_0 under saline soil.

Effect on potassium uptake: Regardless the soils effect, results presented in Table (3) indicate that increasing K rates resulted in significant increases in K-uptake by straw and grains of barley plants. The increases were progressive with increasing K rates, also the increases were significant up to the higher level of K (R_3). However, the increase of R_3 over R_2 in straw was not significant. The main effect of K rates on straw showed increases of 26.8, 53.9 and 62.2 %, while they were 40.7, 51.3 and 67.7 % in grains at R_1, R_2 and R_3, respectively as compared with R_0. Data also reveal that the highest values of K-uptake by barley straw and grains were attained under the saline soil followed by sodic soil and saline sodic soil in decreasing order. Moreover, data in Table (3) show that K-uptake by straw under saline and sodic soils was 4.82 and 3.37 times and by grains was 2.38 and 1.59 times, respectively as compared with K-uptake under saline sodic soil. The highest K-uptake by straw and grains by increasing K rates under salinity conditions may be due to increasing needs to K by plant for osmotic and adjustment under high salinity. Also, the decrease in K-uptake by barley straw and grains under saline sodic conditions could be attributed to the low dry matter yield obtained under such conditions. It may be also attributed to an antagonistic effect of sodium on potassium uptake and hence the increasing percentage of excess sodium ions in the root medium may affect adversely the absorption of potassium by plants.

The interaction between the used soils and K rates did not show any significantly effect on K-uptake by straw, but this pattern of response induced significantly effect on K-uptake by barley grains. Generally, the highest values of K-uptake by straw and grains were attained at R_3 under saline soil conditions, while the lowest values were attained at R_0 under saline sodic soil conditions. These results were confirmed by Sherif *et al*.[20] who reported that values of K-uptake were increased as K rate increased.

Effect on Na-uptake: The effect of K rates on Na-uptake by straw and grains of barley plants grown on different salt affected soils is illustrated in Table (4). Results show that application of K at different rates (R_1, R_2 and R_3) significantly increased Na-uptake by both straw and grains of barley plants, Regardless the effect of the used soils. The main effect of K rates showed increases in Na-uptake by straw and grains of 15.72, 37.49 and 92.22%;13.93, 34.24 and 47.95 % at R_1, R_2 and R_3, respectively as compared with R_0. Such pattern of response occurred in the different soils, where each increase in K rates was accompanied with an associated increase in Na-uptake by straw and grains. Similar findings were obtained by Zid [8] who found that increasing the rates of K did not limit the uptake and accumulation of sodium but resulted in excessive K-uptake.

Data in Table (4) also show significant effect of the used soils on Na-uptake by straw and grains of barley plants grown herein. The highest values of Na-uptake by straw were attained under saline soil followed by sodic soil and saline sodic soil conditions in decreasing order.

Table 4: Effect of K-fertilizer on Na, Ca and Mg uptake (mg/pot) by straw and grains of barley plants grown on different salt affected soils (saline, sodic and saline sodic soils).

Treatment		Uptake of Na, Ca and Mg (mg/pot)					
		Na		Ca		Mg	
Soil	K rates*	Straw	Grains	Straw	Grains	Straw	Grains
Saline	R_0	238.37	28.47	126.46	37.33	30.02	17.08
	R_1	275.93	28.83	147.69	42.51	34.16	17.52
	R_2	295.30	37.43	165.52	53.09	34.92	18.96
	R_3	300.10	49.27	180.75	79.50	53.59	19.63
	mean	277.43	35.50	155.11	53.11	38.17	18.23
Sodic	R_0	117.73	37.33	316.37	138.19	70.58	18.90
	R_1	172.27	39.07	317.07	138.92	72.70	35.08
	R_2	257.90	44.20	384.48	150.39	82.94	39.76
	R_3	259.93	48.23	397.52	162.91	89.87	46.15
	mean	216.83	42.21	353.88	147.60	79.02	34.97
Saline sodic	R_0	79.97	18.90	200.58	55.41	41.74	19.08
	R_1	127.50	26.33	244.93	90.33	59.97	34.63
	R_2	130.28	29.40	295.74	135.40	63.02	36.04
	R_3	344.43	24.87	279.95	148.31	73.33	36.17
	mean	170.36	25.63	255.30	107.46	58.02	31.48
Means of	R_0	165.36	27.57	214.47	77.11	47.45	18.35
K rates	R_1	191.90	31.41	236.56	90.59	55.61	29.08
	R_2	227.82	37.01	281.90	112.24	60.29	31.50
	R_3	286.07	40.79	286.07	130.24	72.26	33.98
Soils	LSD 5 %	36.32	6.11	17.48	22.51	19.10	12.00
	LSD 1%	49.37	9.41	34.94	30.59	25.17	20.80
K-rates	LSD 5 %	25.10	3.50	20.11	17.10	4.11	2.10
	LSD 1%	37.11	6.33	34.00	25.11	8.01	4.66
Interactions	LSD 5 %	36.26	8.79	34.87	25.01	20.30	17.51
	LSD 1%	49.39	11.80	47.50	33.68	27.65	23.86

* K rates: R_0: 0 mg K/kg soil; R_1: 12 mg K/kg soil; R_2: 24 mg K/kg soil and R_3: 48 mg K/kg soil

The Na-uptake by straw under saline soil was significantly higher as compared with those obtained under sodic and saline sodic soil conditions. Concerning Na-uptake by grains of barley plants under sodic soil, it was significantly higher as compared with those obtained under saline and saline sodic conditions. This effect seems to be dependant on soil properties that determined the buffering capacity and native nutrients content. Na-uptake values by grains of barley plants grown on sodic soil conditions (Table 4) were 1.19 and 1.65 times than those obtained by plants grown on saline and saline sodic conditions, respectively. Also, data show that the interaction between the used soils and K rates has a significant effect on Na-uptake by straw and grains. The highest values of Na-uptake by straw was found at R_3 under saline sodic soil and the lowest one was attained at R_0 under saline sodic soil conditions. Moreover, the highest value of Na-uptake by grains was found at R_3 under saline soil and the lowest one was found at R_0 under saline sodic soil conditions.

Effect on Ca-uptake: Data presented in Table (4) show that K rates significantly increased Ca-uptake by straw and grains of barley plants over all soils. However, these increases did not reach the level of significance at 5% when R_2 compared with R_3 in straw and R_0 with R_1 in grains. The main effect of K rates showed increases in Ca-uptake of 10.30, 31.44 and 33.39 % in straw and 16.86, 46.49 and 68.90 % in grains at R_1, R_2 and R_3, respectively as compared with R_0 (control).

Data in Table (4) show that Ca-uptake by straw and grains significantly affected by the different used soils. The highest levels of Ca-uptake by straw and grains were obtained under sodic soil followed by saline sodic and saline soil conditions in decreasing order. Calcium uptake values in straw and grains of barley plants grown on sodic soil were 1.40, 2.28 and 1.37 and 2.78 times than those grown on saline sodic and saline soils, respectively. From the above mentioned result it can be concluded that application of K has pronounced effects on Ca-uptake by both straw and grains of barley plants grown on different salt affected soil conditions.

Effect on Mg-uptake: Data in Table (4) show the effect of increasing K rates on Mg-uptake by straw and grains of barley grown on saline, sodic and saline sodic soils. Results show a significant progressive increase in Mg-uptake by straw and grains of barley plants with increasing K rates. The main effect of K rates showed increases in Mg-uptake of 17.20, 27.06 and 52.29 % in straw and 58.17, 71.66 and 85.18 % in grains at R_1, R_2 and R_3, respectively as compared with untreated treatment (R_0).

Data also show significant effect of the used soils on Mg-uptake by straw and grains of barley plants grown on these soils. The highest levels of Mg-uptake by straw and grains were obtained in plants grown on sodic soil followed by saline sodic and saline soil conditions in decreasing order. Mg-uptake by straw and grains under sodic conditions was 1.36, 2.07 and 1.11 and 1.92 times as compared with those obtained under saline sodic and saline soils, respectively.

The interaction between the used soils and K rates had a significant effect on Mg-uptake by straw and grains of barley plants. The highest values of Mg-uptake by both straw and grains were obtained at R_3 under sodic soil and the lowest values were found at R_0 under saline soil.

Generally, Mg-uptake by straw and grains of barley plants grown on all the tested soils, took the same trend of Ca-uptake as affected by K rates and salt affected soils. Similar results were reported by Sherif *et al.* [20].

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