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EFFECT OF IRRIGATION WATER QUALITY ON SOME SOIL AND SORGHUM PLANT CHARACTERS

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ABSTRACT: A pot experiment was conducted at El-Gemmeiza Agric. Res. Station, El-Gharbia Governorate to study the effect of irrigation water quality on soil properties and productivity of Sudan grass grown on clay loam soil. The obtained results of soil and plant were passed through a triangle computer programme, hence thirteen irrigation water treatments were used to cover all the possible combinations of Ca^{2+}, Mg^{2+} and Na^{+} salts in irrigation water at different salinity levels. The obtained results can be summarized as follows :

1. **An increase in soil pH; soil electrical conductivity (EC); exchangeable Ca^{2+}, Mg^{2+} and Na^{+}; bulk density; hydraulic conductivity; structure factor; and soil capillary pores were detected by increasing salinity levels. But, the values of soil available water and soil, large and medium, pores were decreased by increasing salinity levels.**
2. **The values of plant proline were increased by increasing salinity levels. On contrary, the values of total forage yield of Sudan grass were generally decreased by increasing salinity levels.**

Key words: Irrigation water quality, soil chemical and physical properties, Sudan grass, proline content.

INTRODUCTION

Low quality water is recently considered to be used in agriculture expansion, (Abdel-Rasheed, 1996).

The major problem of using poor quality water for agricultural irrigation are: 1) the high amount of salt content, 2) the kind of salts and the ratio between the cations and 3) specific ion toxicity level.

However, to avoid salt accumulation to be an excess level and to prevent the build up of salinity, it is needed to apply a leaching fraction (FAO, 1992).

Gupta (1980) reported that soil pH and SAR tended to increase under high sodium water, this phenomenon decreased when gypsum was applied. While Puntamkar et al. (1988) found that the soil pH is not greatly affected by irrigation with saline water.

Abo El-Defan (1990) stated that the use of different saline water increased soil EC values over the control. This effect was more pronounced with highly salinity level (10000 ppm). Abd El-Nour (1989) found that the concentration of soluble Ca^{2+}, Mg^{2+}, K^+ and Na^+ were sharply increased as a result of increasing salinity level of irrigation water up to 4000 ppm. Alawi et al. (1980) found that irrigation of clay soil by saline water leads to a marked accumulation of soluble salts, especially chlorides, while there was no detected changes in the concentration of HCO^-_3.

Yadav (1978) concluded that increasing the Mg^{2+}/Ca^{2+} ratio of the irrigation water at constant electrolyte concentration has increased the content of Na^+ and Mg^{2+} on exchangeable complex, whereas the exchangeable Ca^{2+} content decreased.

The soil physical properties are indirectly affected by the quality of irrigation water through its effect on the soil chemical properties which will change in turn the porosity status of the soil which is known as a very important parameter that governs structure and water movement in soil.

On the other hand, some forage species such as Sudan grass (*Sorghum Vulgar Var. Sudanense*), one of such important crops which is adapted to tropical, sub-tropical and temperate areas, beside their ability to adapt under stress conditions (Sohsah, 1992).

The aim of this work is to study the effect of low quality irrigation water which have different Ca^{2+} : Mg^{2+} : Na^+ ratios on some soil physical and chemical properties, and the ability of Sudan grass to adapt under these conditions.

MATERIALS AND METHODS

. A pot experiment was carried out at El-Gemmeiza Agriculture Research Station, El-Gharbia Governorate in an open system under prevailing conditions. Polyethylene pots, 30 cm in height and 20.7 cm in diameter, were filled with 7.0 Kg of clay loam soil, placed over 0.5 Kg of dried washed sand per pot, which had a hole at bottom to facilitate flushing and to stay salinity at field capacity. Some physical and chemical properties of soil are shown in Table 1. Soil were enough compacted in the pots to a depth of 19.3 cm, in order to reach and keep a constant bulk density (1.08 g/cm^3).

The three factors computer model (Moussa, 1987) was applied in this study using calcium, magnesium and sodium salts as x_1,x_2 and x_3, respectively, placed at the heads of a triangle similar to that used in describing soil texture. The sum of the three factors must be equal to 1 or 100% of the maximum values, i.e., $x_1+x_2+x_3 = 100\%$. The level of each factor decreases gradually when moving from the concerned head towards the opposite side at which the level reaches to zero or a minimum. The diagram will show 66 intersection points, which will cover all the possible combinations between the three factors, Fig. 1. The actual thirteen combined treatments are illustrated in Fig. 2 and presented in Table 2.

Table 1 : Some physical and chemical properties of the investigated soil

Soil physical properties

Bulk density, Db (g/cm3)	Real density, Dr (g/cm3)	Total soil porosity, E, %	Hydraulic conductivity, HC (cm/hr)	Particle size distribution ,%					Aggregation percent	Structure Factor, %	Pore size distribution, %			Moisture content, % Applied pressure, (bar)			Available water, AW, %
				Coarse sand	Fine sand	Silt	Clay	Texture class	<20µ	<2µ	>9µ	9-0.2µ	< 0.2µ	0	0.33	15	
1.08	2.62	58.78	0.06	0.30	29.80	41.20	28.70	Clay loam	29.22	64.19	20.95	23.29	20.68	64.92	43.97	20.68	23.29

Soil chemical properties

EC (dSm^{-1})	pH, soil suspension 1:2.5	Soluble ions in soil saturation extract (meq/l)							Exchangeable cations (meq/100g soil)				CEC meq/100 soil)	Total carbonate, %	Organic matter, O.M, %
		Cations				Anions									
		Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+			
2.02	7.73	7.91	6.11	6.90	0.10	3.78	10.97	6.27	31.99	10.02	4.14	0.37	46.52	2.04	1.96

Five concentrations of saline solutions were prepared, i.e., 1000, 2500, 5000, 10000 ppm and 10000 ppm plus 30% leaching fraction LF). Thirteen solution for each concentration were prepared using Ca^{2+}, Mg^{2+}, Na^{+} chloride and sulphate salts. The ratio of chlorides to sulphates was kept to be (1:1). Each treatment was replicated 3 times.The composition of the used saline solutions are illustrated in Table 3.

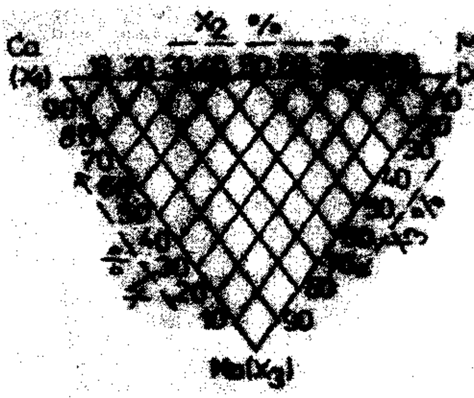


Fig.(1): Guide for the Ca(X_1), Mg(X_2), Na(X_3) combination of each point.

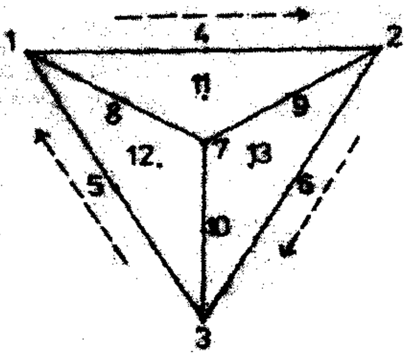


Fig. (2): Treatments sites on the triangle diagram.

Table 2:The chosen combination of thirteen treatments of the computer model

Treatment NO.	Relative fractional as unit			Relative concentration percentages		
	Ca(X_1)	Mg(X_2)	Na(X_3)	Ca(X_1)	Mg(X_2)	Na(X_3)
1	1	0	0	100	0	0
2	0	1	0	0	100	0
3	0	0	1	0	0	100
4	1 / 2	1 / 2	0	50	50	0
5	1 / 2	0	1 / 2	50	0	50
6	0	1 / 2	1 / 2	0	50	50
7	1 / 3	1 / 3	1 / 3	33.3	33.3	33.3
8	4 / 6	1 / 6	1 / 6	66.6	16.6	16.6
9	1 / 6	4 / 6	1 / 6	16.6	66.6	16.6
10	1 / 6	1 / 6	4 / 6	16.6	16.6	66.6
11	4 / 9	4 / 9	1 / 9	44.4	44.4	11.1
12	4 / 9	1 / 9	4 / 9	44.4	11.1	44.4
13	1 / 9	4 / 9	4 / 9	11.1	44.4	44.4

Table 3 : Composition of irrigation water at different salinity levels

Salinity level (ppm)	Treatment No.	Amount of cations (meq/l)			Amount of cations (mg/l)			Amount of salts (mg/l)					
		Ca^{2+}	Mg^{2+}	Na^+	Ca^{2+}	Mg^{2+}	Na^+	$CaCl_2$	$CaSO_4$	$MgCl_2$ $6H_2O$	$MgSO_4$	NaCl	Na_2SO_4
1000	1	16.20	-	-	323	-	-	451	549	-	-	-	-
	2	-	12.15	-	-	145	-	-	-	662	338	-	-
	3	-	-	15.44	-	-	355	-	-	-	-	451	549
	4	6.90	7.05	-	138	84	-	189	238	367	206	-	-
	5	7.92	-	7.89	158	-	181	220	269	-	-	232	279
	6	-	6.89	6.75	-	82	155	-	-	362	200	195	243
	7	4.77	4.85	4.79	95	58	110	131	164	251	143	139	172
	8	10.07	2.60	2.59	201	31	59	279	343	132	78	76	92
	9	1.60	9.58	1.65	32	115	38	44	60	500	284	48	64
	10	2.36	2.41	10.16	47	28	233	65	81	125	71	297	361
	11	6.39	6.48	1.21	127	77	27	176	219	335	191	34	45
	12	6.84	1.65	6.84	136	19	157	190	233	85	49	200	243
	13	1.40	6.29	6.18	28	75	142	37	50	328	184	179	222
2500	1	40.50	-	-	810	-	-	1128	1372	-	-	-	-
	2	-	30.38	-	-	364	-	-	-	1655	845	-	-
	3	-	-	38.60	-	-	887	-	-	-	-	1128	1372
	4	17.22	17.64	-	344	211	-	472	593	920	515	-	-
	5	19.79	-	19.73	395	-	454	550	672	-	-	578	700
	6	-	17.27	18.42	-	207	423	-	-	906	501	486	607
	7	11.95	12.15	11.95	239	145	275	329	410	628	358	347	428
	8	25.71	6.27	6.23	514	75	143	713	875	321	187	182	222
	9	4.18	24.14	4.30	83	289	99	110	150	1250	710	120	160
	10	5.88	6.01	19.07	117	72	438	162	202	311	177	743	905
	11	15.96	16.22	3.03	319	194	69	439	548	838	478	85	112
	12	17.11	4.14	17.09	342	49	393	474	583	213	123	499	608
	13	2.75	16.06	15.81	55	192	363	72	99	832	472	458	567
5000	1	82.14	-	-	1642	-	-	2600	2400	-	-	-	-
	2	-	60.77	-	-	729	-	-	-	3310	1690	-	-
	3	-	-	77.21	-	-	1775	-	-	-	-	2256	2744
	4	34.44	35.29	-	688	423	-	943	1187	1840	1030	-	-
	5	39.55	-	39.51	791	-	908	1099	1343	-	-	1157	1401
	6	-	34.52	33.74	-	414	776	-	-	1811	1001	972	1216
	7	23.89	24.28	23.96	477	291	551	657	820	1255	715	695	858
	8	51.47	12.53	12.45	1029	150	286	1427	1752	641	373	363	444
	9	8.39	48.29	8.59	167	279	197	220	301	2500	1420	239	320
	10	11.79	12.01	50.89	235	144	1170	324	405	622	353	1486	1810
	11	31.40	32.01	7.24	628	384	166	863	1078	1659	940	253	207
	12	34.19	8.29	34.22	683	99	787	948	1164	426	246	1000	1216
	13	5.50	32.11	31.65	110	385	727	144	198	1663	944	918	1133
10000	1	172.23	-	-	3444	-	-	7600	2400	-	-	-	-
	2	-	121.54	-	-	1458	-	-	-	6621	3379	-	-
	3	-	-	154.42	-	-	3551	-	-	-	-	4512	5488
	4	69.25	70.91	-	1385	851	-	2106	2129	3693	2072	-	-
	5	79.61	-	79.39	1592	-	1826	2460	2400	-	-	2326	2814
	6	-	69.07	67.45	-	828	1551	-	-	3624	2002	1943	2431
	7	47.77	48.56	47.94	955	582	1102	1314	1639	2510	1430	1391	1716
	8	104.12	25.95	26.00	2082	311	598	3820	2400	1317	779	761	923
	9	16.76	69.61	17.18	335	1159	395	440	601	5000	2841	478	640
	10	23.58	24.02	101.78	471	288	2341	648	810	1244	706	2971	3621
	11	63.87	64.91	12.09	1277	779	278	1757	2191	3353	1913	339	447
	12	68.42	16.56	68.43	1368	198	1574	1896	2330	851	491	1999	2433
	13	10.71	64.36	63.46	214	772	1459	292	371	3332	1892	1840	2273

Addition amount of saline irrigation water was equal to water quantity at field capacity plus 20% LF.

Seeds of Sudan grass (*Sorghum Vulgare Var. Sudanense*) were sown at 1 cm depth. Tap water was applied till the emergence follows by the prepared saline water. The basel doses of N, P and K were applied according to the recommendations. Phosphorus fertilizer was added at 30 Kg P_2O_5/fed during land preparation. Nitrogen fertilizer was applied at a rate of 40 Kg N/fed which splitted into three equal portions, the 1st portion was applied before the 2nd irrigation while the 2nd portion was added after the first cut and the 3rd portion was added after the 2nd cut. Potassium fertilizer was added at 24 Kg K_2O/fed in one dose with the first 1st dose of nitrogen. Four cuts of Sorghum plants were taken during the growth season along 165 days. At each cut, some growth characters were recorded; fresh weight (g/pot) and dry weight (g/pot) while total fresh yield (g/pot) and total dry yield (g/pot) were calculated by summation of the weight for all cuts during the growth season. Chemical analyses of plant were carried out according to Cottenie (1980) and Bates (1973).

At the end of season, some physical and chemical analyses of soil were carried out according to Richards (1954), Black (1965) and Page *et al.* (1982).

RESULTS AND DISCUSSION

I. Effect of Different Combinations of Ca^{2+}, Mg^{2+} and Na^+ in Irrigation Water at Different Salinity Levels on Some Chemical Properties of Soil

1. Soil reaction (pH)

Data in Table 4 reveal that there are no wide variations between the original thirteen treatments in soil pH. Generally, the pH values were slightly differed with increasing salinity levels. However, the maximum pH values were obtained when the irrigation water had 100% Na. These results may be attributed to the soil buffering capacity. Similar results were obtained by Puntamkar et al. (1988). The soil pH values under the individual effect of Ca^{2+}, Mg^{2+} and Na^+ were 7.33, 7.42, 7.54 and 7.08, 7.38, 7.90 for 1000 and 10000 ppm salinity levels, respectively. The single effect was taken the order $Na^+ > Mg^{2+} > Ca^{2+}$ for its effect on the pH values. Similar conclusion was observed by Gupta (1980).

2. Soil salinity

Data recorded in Table 4 show that the soil EC values were generally increased by increasing irrigation water concentration from 1000 to 10000 ppm, then decreased at (10000+30% LF). The maximum soil EC values were obtained when the irrigation water had 100% Na^+, Fig. 3, values were 11.87, 36.17 and 22.67 dSm^{-1} for 1000, 10000 and (10000+ 30% LF) ppm, respectively, as compared to control value (2.02 dSm^{-1}). Similar results were obtained by Abo El-Defan (1990). It is obvious from Fig. 3 that the three individual treatments at salinity level of 1000 ppm Ca^{2+}, Mg^{2+} and Na^+ gave 90, 70 and 100% of the maximum value, or 10.84, 8.94 and 11.87 $dSm\text{-}^1$, respectively. These results declare that, the individual sodium treatment was more effective than either calcium or magnesium on soil EC value, while magnesium has the lowest one. Also, it is clear that the highest soil EC zone was near to Na cation which resulted in 90% of the maximum soil EC value. On the other hand, added 30% leaching fraction to saline irrigation water of 10000 ppm leads to decrease the individual Na effect rather than the other two cations. This suggest that the leaching fraction has a pronounced effect on Na^+ salts rather than Mg^{2+} or Ca^{2+} salts, Fig.4. However the maximum soil EC value (22.67 dSm^{-1}) was obtained by the combination consists of 40, 30, 30 % of Ca^{2+}, Mg^{2+} and Na^+, respectively, under salinity level of (10000 ppm + 30% LF).

3. Exchangeable cations

Data in Table 4 reveal that the maximum values of exchangeable Ca^{2+} were increased with increasing its concentration in the irrigation water. The values were 31.65, 36.37 and 36.39 meq/100g soil for saline irrigation water of 1000, 10000 and (10000+30%LF) ppm, respectively compared with that of the control value (31.99 meq/100g soil). Similar results were obtained by Babcock et al. (1959) who noted that the amounts of exchangeable Ca^{2+} tended to increase when the irrigation water contain high Ca^{2+}.

Referring to exchangeable Mg, the results presented in Table 4 show that the maximum values of exchangeable Mg^{2+} were gradually

Table 4 : Some chemical and physical properties of soil as affected by different combinations of Ca^{2+} , Mg^{2+} and Na^{+} in irrigation water at different salinity level (mean values of the original thirteen treatments)

Salinity Levels, ppm	Treatment No.	EC (dSm-1)	pH Soil suspension (1:2.5)	Exchangeable cations (meq/100 g soil)				Bulk density (gm/cm3)	Hydraulic conductivity (cm/hr)	Structure factor ,%	Available water, %	Pore size distribution, %		
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}					> 9μ	9 - 0.2μ	< 0.2μ
1000	1	10.84	7.33	31.65	10.27	4.38	0.41	1.07	0.17	69.62	19.06	30.05	19.06	21.41
	2	8.94	7.42	29.01	13.42	4.00	0.40	1.05	0.10	62.58	19.62	34.69	19.62	23.45
	3	11.87	7.54	21.29	9.00	15.30	0.50	1.02	0.18	64.51	18.71	13.47	18.71	27.57
	4	8.54	7.40	31.18	11.00	3.98	0.33	1.05	0.20	66.94	16.88	33.27	16.88	28.39
	5	9.02	7.53	31.40	9.45	4.86	0.38	1.03	0.17	64.75	20.84	26.33	20.84	23.24
	6	10.19	7.56	28.91	11.98	4.91	0.39	1.11	0.24	65.63	16.48	19.63	16.48	29.17
	7	11.31	7.42	27.54	11.55	6.61	0.39	1.11	0.22	62.58	21.71	23.49	21.71	24.46
	8	10.97	7.42	31.11	9.82	4.85	0.40	1.01	0.28	64.52	21.51	23.22	21.51	22.18
	9	9.50	7.51	28.07	12.84	4.84	0.34	1.01	0.12	66.29	23.29	25.63	23.29	19.42
	10	9.43	7.65	27.66	10.35	8.19	0.41	1.05	0.28	63.93	21.25	17.66	21.25	22.59
	11	6.47	7.50	31.19	10.65	3.87	0.38	1.06	0.24	66.01	17.22	21.82	17.22	26.89
	12	7.89	7.58	31.07	10.41	4.23	0.38	1.06	0.14	65.86	20.38	26.97	20.38	22.01
	13	8.70	7.57	30.68	10.39	4.63	0.37	1.08	0.11	67.69	20.29	22.05	20.29	23.60
2500	1	11.14	7.25	32.40	9.51	3.77	0.49	1.07	0.22	72.82	17.70	27.88	17.70	23.66
	2	10.89	7.39	23.19	18.84	3.53	0.51	1.05	0.19	69.84	17.51	23.69	17.51	25.92
	3	13.42	7.64	15.42	8.20	21.83	0.62	1.04	0.17	59.14	17.76	15.05	17.76	30.08
	4	12.38	7.29	31.28	11.10	3.67	0.43	1.09	0.26	73.07	15.48	19.59	15.48	29.95
	5	12.76	7.43	31.85	8.78	5.41	0.56	1.08	0.31	69.57	20.60	23.04	20.60	24.66
	6	12.16	7.54	22.25	15.62	7.73	0.49	1.12	0.24	68.81	16.96	16.33	16.96	29.84
	7	12.51	7.41	24.48	14.62	6.81	0.56	1.13	0.23	64.25	20.80	18.67	20.80	25.72
	8	11.18	7.34	31.83	9.73	4.76	0.49	1.03	0.33	65.54	20.60	20.31	20.60	23.89
	9	11.54	7.37	23.76	16.97	4.82	0.52	1.03	0.14	73.87	20.55	23.46	20.55	22.20
	10	10.19	7.55	24.81	9.18	12.12	0.59	1.07	0.26	60.53	20.00	18.15	20.00	23.90
	11	10.19	7.33	31.49	10.97	3.42	0.46	1.08	0.29	68.49	16.64	17.83	16.64	28.79
	12	9.06	7.48	31.36	9.45	4.74	0.54	1.10	0.16	69.07	18.55	25.38	18.55	24.81
	13	10.75	7.51	26.38	13.31	6.29	0.62	1.09	0.19	72.85	18.23	19.33	18.23	26.07
5000	1	16.82	7.18	34.13	7.44	3.75	0.77	1.10	0.24	75.81	13.54	22.26	13.54	28.50
	2	15.87	7.33	16.97	25.36	3.34	0.80	1.13	0.29	72.58	13.55	19.62	13.55	30.24
	3	20.98	7.78	8.87	7.98	28.32	0.83	1.12	0.17	58.73	17.58	16.89	17.58	32.15
	4	18.40	7.22	31.42	11.23	3.11	0.71	1.12	0.28	76.50	12.81	17.06	13.81	33.77
	5	18.78	7.37	32.40	7.78	5.94	0.61	1.17	0.38	73.93	17.91	22.62	17.91	27.61
	6	18.56	7.45	14.12	17.33	14.43	0.60	1.13	0.32	72.58	14.13	14.94	14.13	33.76
	7	19.18	7.37	23.07	15.41	7.39	0.73	1.15	0.29	68.23	20.07	16.95	20.07	27.38
	8	15.48	7.24	32.93	8.50	4.40	0.57	1.06	0.43	67.38	19.70	19.31	19.70	25.47
	9	15.54	7.34	22.39	18.64	4.77	0.66	1.08	0.31	74.68	14.03	21.31	14.03	29.67
	10	16.14	7.53	21.28	6.98	17.18	0.63	1.09	0.24	58.93	15.66	21.92	15.66	30.00
	11	13.60	7.27	31.65	11.03	3.12	0.68	1.09	0.30	69.62	14.59	16.47	14.59	31.10
	12	13.86	7.41	32.76	7.76	5.04	0.61	1.11	0.24	71.18	13.48	24.76	13.48	30.12
	13	13.39	7.42	16.42	16.51	12.61	0.65	1.10	0.19	76.67	15.38	15.10	15.38	29.81

Table 4 : (continued)

Salinity Levels, ppm	Treatment No.	EC (dSm-1)	pH Soil suspension (1:2.5)	Exchangeable cations (meq/100 g soil)				Bulk density (gm/cm3)	Hydraulic conductivity (cm/hr)	Structure factor ,%	Available water, %	Pore size distribution, %		
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}					> 9μ	9 - 0.2μ	< 0.2μ
10000	1	33.18	7.08	36.37	6.61	2.23	0.86	1.13	0.32	75.94	13.13	17.78	13.13	30.31
	2	32.50	7.38	10.60	32.89	2.16	0.83	1.13	0.56	74.89	11.56	17.56	11.56	33.56
	3	36.17	7.90	8.59	7.30	29.87	0.84	1.12	0.16	55.81	17.54	18.13	17.54	34.77
	4	28.45	7.23	31.83	11.64	2.36	0.77	1.13	0.69	77.21	11.27	14.09	11.27	35.87
	5	30.90	7.40	33.22	6.23	6.45	0.69	1.19	0.58	76.94	12.84	21.36	12.84	33.87
	6	29.67	7.59	7.96	20.48	17.07	0.66	1.15	0.52	75.89	13.48	11.80	13.48	36.67
	7	28.00	7.40	17.08	15.86	12.34	0.80	1.18	0.36	73.55	17.04	15.88	17.04	30.91
	8	29.70	7.28	33.99	7.63	4.35	0.73	1.09	0.45	69.35	18.41	18.57	18.41	27.21
	9	29.15	7.45	18.91	21.87	4.68	0.72	1.10	0.32	75.81	10.59	20.89	10.59	33.43
	10	27.65	7.70	19.36	4.63	21.88	0.64	1.09	0.23	56.42	14.64	24.58	14.64	31.85
	11	25.35	7.29	32.02	11.33	2.41	0.73	1.09	0.33	76.56	12.09	15.68	12.09	34.15
	12	26.50	7.48	33.84	5.72	6.48	0.69	1.12	0.29	78.50	12.02	16.08	12.02	34.93
	13	24.17	7.53	11.73	18.66	15.42	0.66	1.14	0.22	78.76	14.71	11.35	14.71	34.08
10000+30% LF	1	20.67	7.22	36.39	7.13	1.68	0.81	1.09	0.30	76.88	10.30	28.78	10.30	30.34
	2	19.93	7.51	11.22	32.46	2.03	0.80	1.07	0.50	81.72	11.11	21.19	11.11	31.54
	3	16.45	7.94	7.75	6.69	31.05	0.76	1.14	0:16	57.47	17.93	22.12	17.93	34.63
	4	18.25	7.34	31.94	11.33	2.15	0.76	1.06	0.66	81.72	11.51	20.65	11.51	35.92
	5	18.94	7.47	33.35	5.89	6.53	0.71	1.04	0.59	76.78	10.90	27.06	10.90	36.98
	6	18.27	7.65	5.67	20.25	19.75	0.49	1.08	0.56	76.02	13.82	20.62	13.82	38.11
	7	22.70	7.45	20.61	15.00	10.14	0.76	1.06	0.34	76.40	16.64	27.43	16.64	31.58
	8	22.30	7.34	33.31	7.84	4.28	0.72	1.09	0.30	73.87	11.98	23.80	11.98	33.36
	9	16.39	7.52	19.54	21.84	4.53	0.69	1.07	0.31	74.41	11.05	24.27	11.05	33.43
	10	18.87	7.73	19.85	5.48	20.21	0.64	1.04	0.26	58.14	11.08	25.86	11.08	35.69
	11	20.37	7.37	32.07	11.37	2.33	0.71	1.04	0.33	78.76	11.42	17.60	11.42	34.27
	12	21.85	7.49	32.89	6.21	6.38	0.74	1.02	0.29	77.47	11.14	19.38	11.14	34.88
	13	18.90	7.59	9.59	19.81	16.02	0.76	1.07	0.24	75.00	13.14	14.98	13.14	34.47
Control		2.02	7.73	31.99	10.02	4.14	0.37	1.08	0.06	46.19	23.29	20.95	23.29	20.68

LF = leaching fraction

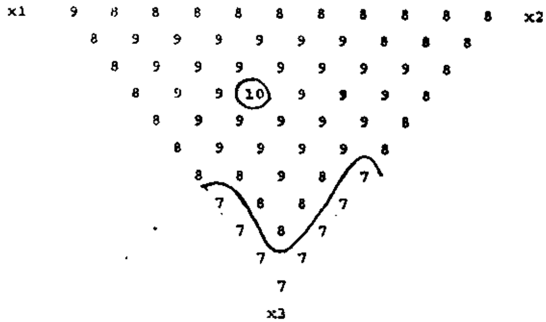
increased by increasing salinity levels from 13.42 to 32.89 then 32.46 meq/100g soil for saline irrigation water levels of 1000 to 10000 and (10000+30% LF) ppm, respectively, compared with that of control value (10.02 meq/ 100g soil). Similar conclusion was obtained by Yadav (1978).

However, it can be noticed that at low salinity level (1000 ppm), the exchangeable Mg^{2+} values were not less than 60% of the maximum value. While increasing salinity level up to 10000 ppm decreased the values of exchangeable Mg^{2+} to be 20% of the maximum value; even when Ca^{2+} or Na^{+} were 100%. These observations concluded that, at high concentration of irrigation water salinity, the binding energy of Ca^{2+} or Na^{+} sites are equal to

```
                    DATA
                  Replicates
            I          II          III
     1  10.6300    11.4300    10.4700
     2   9.5800     9.0000     8.2400
     3  11.8700    13.1600    10.5900
     4   9.0500     8.5400     8.0300
  T  5   9.0200    10.0200     8.0300
  r  6  10.7700    10.2400     9.5500
  e  7  10.3600    10.9400    12.6400
  a  8  10.9700    11.6000    10.3500
  t  9  10.1900     8.8200     9.5000
  m 10   9.4300     9.4300     9.4400
  e 11   6.3800     6.7200     6.3200
  n 12   7.8900     6.9200     8.8600
  t 13   8.1700     9.3900     8.5500
  s
   AVERAGE VALUE      :

    10.8433    8.9400   11.8733    8.5400    9.0233   10.1867   11.3133
    10.9733    9.5033    9.4333    6.4733    7.8900    8.7033

  COEFF.DITER.= .8424945
    CORRELATION COEFFICINT= .917875

  CRITERION FISHER F( 12.000 26.000) 11.58947
     SOCT= .7662575
  CONTROL 6.473334 - 0 = 6.473334        t= 11.54881
  CONTROL 7.89 - 0 = 7.89        t= 14.07623
  CONTROL 8.703334 - 10.18296 =-1.47963       t= 2.639747

       10.8433       10.1664        9.5976        9.1369        8.7844        8.5400
        8.4037        8.3756        8.4556        8.6437        8.9400

       10.1057       10.1069       10.0814       10.0291        9.9501        9.8443
        9.7119        9.5527        9.3668        9.1541

        9.5549       10.0994       10.4822       10.7034       10.7631       10.6612
       10.3977        9.9726        9.3859

        9.1909       10.1437       10.8001       11.1600       11.2235       10.9905
       10.4611        9.6352

        9.0137       10.2401       11.0351       11.3988       11.3312       10.8323
        9.9021

        9.0233       10.3883       11.1872       11.4198       11.0863       10.1867

        9.2197       10.5885       11.2563       11.2231       10.4888

        9.6029       10.8407       11.2426       10.8085

       10.1729       11.1448       11.1459

       10.9297       11.5008

       11.8733

 Ymax= 11.87333               Ymin= 8.3756
```

Fig. 3. Soil salinity as affected by all the possible combinations of Ca^{2+}, Mg^{2+} and Na^{+} for saline irrigation water of 1000 ppm. (represents the salinity levels from 1000 to 10000 ppm).

```
                  DATA
               Replicates
            I          II         III
    1   20.8000    21.5000    19.7000
    2   19.6000    19.7000    20.5000
    3   15.1000    16.4500    17.8000
    4   19.4000    18.2500    17.1000
T   5   17.9500    19.9300    18.9400
r   6   19.0800    18.2700    17.4600
e   7   22.7000    23.4000    22.0000
a   8   22.3000    21.5000    23.1000
t   9   16.8300    15.5400    16.8000
m  10   18.8700    17.9000    19.8500
e  11   20.6500    20.7500    19.7000
n  12   21.2000    22.5000    21.8500
t  13   19.9000    18.9000    17.9000
s

 AVERAGE VALUE      :

   20.6667   19.9333   16.4500   18.2500   18.9400   18.2700   22.7000
   22.3000   16.3900   18.8733   20.3667   21.8500   18.9000

COEFF.DITER.= .877847
  CORRELATION COEFFICINT= .9369349

CRITERION FISHER F( 12.000 26.000) 15.57066
   SOCT= .8870456
CONTROL 20.36667 - 0 = 20.36667        t= 31.38759
CONTROL 21.85 - 0 = 21.85        t= 33.6736
CONTROL 18.9 - 19.69111 =-.791111        t= 1.219202

      20.6667      19.8553      19.2080      18.7247      18.4053      18.2500
      18.2587      18.4313      18.7680      19.2687      19.9333

      20.3824      20.5892      20.7229      20.7835      20.7711      20.6857
      20.5271      20.2956      19.9909      19.6132

      20.0676      21.0554      21.7331      22.1007      22.1582      21.9055
      21.3427      20.4698      19.2868

      19.7223      21.2541      22.2387      22.6761      22.5664      21.9095
      20.7054      18.9541

      19.3464      21.1851      22.2396      22.5099      21.9959      20.6977
      18.6152

      18.9400      20.8486      21.7359      21.6019      20.4466      18.2700

      18.5031      20.2445      20.7275      19.9522      17.9185

      18.0356      19.3728      19.2145      17.5608

      17.5376      18.2334      17.1968

      17.0091      16.8265

      16.4500

Ymax= 22.67615            Ymin= 16.45
```



```
      x1    9   8   8   8   8   8   8   8   8   8   8   x2
              8   9   9   9   9   9   9   8   8   8
                8   9   9   9   9   9   9   9   8
                  8   9   9  10   9   9   9   8
                    8   9   9   9   9   9   8
                      8   9   9   9   9   8
                        8   8   9   8   7
                          7   8   8   7
                            7   8   7
                              7   7
                                7
                                x3
```

Fig. 4. Soil salinity as affected by all the possible combinations of Ca^{2+}, Mg^{2+} and Na^{+} for saline irrigation water of 10000 ppm with 30 % of leaching fraction.

against Mg^{2+}. Whereas, at low irrigation water salinity the binding energy of Ca^{2+} is relatively higher than Na^{+} to against Mg^{2+}.

Concerning the exchangeable Na^{+}, data presented in Table 4 indicate that the values of exchangeable Na^{+} were increased by increasing salinity levels of irrigation water. The maximum values were obtained when the irrigation water had 100% Na^{+}, values were increased from 15.30 to 29.87 then 31.05 meq/100g soil at salinity levels of 1000, 10000 and (10000+30% LF) ppm, respectively. Results declare that the ability of Na^{+} to displace Ca^{2+} or Mg^{2+} were decreased by increasing irrigation water salinity ; but the replacing power of Na^{+} in place of Mg^{2+} is a little more than that of Na^{+} in place of Ca^{2+}. These results were confirmed by Moussa (1987 and 1991).

II. Effect of Different Combinations of Ca^{2+}, Mg^{2+} and Na^{+} in Irrigation Water at Different Salinity Levels on Some Physical Properties of Soil

1. Soil bulk density (Db)

Data presented in Table 4 indicate that soil bulk density values slightly increased by increasing salinity levels. Meanwhile, soil bulk density were decreased with added 30% of leaching fraction to saline irrigation water of 10000 ppm. The individual effect of Ca^{2+}, Mg^{2+} and Na^{+} affected soil bulk density values to be 1.07, 1.05, 1.02 g/cm^{3} under irrigation water of 1000 ppm, then increased to 1.13, 1.13, 1.12 gm/cm^{3} under saline irrigation water of 10000 ppm. While addition of 30% of LF to saline irrigation water of 10000 ppm decreased soil bulk density in case of single Ca^{2+} and Mg^{2+} treatment to be 1.09 and 1.07 gm/cm^{3}, respectively. As for single Na^{+} treatment, soil bulk density was increased to be 1.14 gm/cm^{3}. Similar results were obtained by Lima and Grismer (1992) who found that soil bulk density values which measured at borders irrigated with salty water tended to increase faster, as water content decreased, than at borders irrigated with high water good quality.

2. Soil hydraulic conductivity (HC)

Data in Table 4 reveal that hydraulic conductivity (HC) values were relatively increased with increasing salinity levels of irrigation water, which ranged between 0.10 and 0.28 cm/hr at 1000 ppm; and between 0.16 and 0.69 cm/hr at 10000 ppm as compared with that of control value (0.06 cm/hr). Similar results was obtained by Mostafa *et al.* (1988). It can be noticed that the individual effect of Ca^{2+} on HC values was more than Mg^{2+} especially at low salinity level. At high salinity level, the individual effect of Ca^{2+} was lower than Mg^{2+}. The HC of the individual Na^{+} treatment was slightly decreased by increasing salinity levels; the values were 0.18 and 0.16 cm/hr for saline irrigation water of 1000 and 10000 ppm, respectively. These results are in agreement with Mostafa et al. (1988) and El-Maddah (1988), who reported that the cations increased soil hydraulic conductivity in the order : $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$.

3. Soil structure factor (SF)

Data in Table 4 and Fig. 5 indicate that soil structure factor (SF) increased with increasing salinity levels of irrigation water. The maximum SF value under salinity level of 1000 ppm which was denoted by number 10 was 69.62%; occurred when the irrigation water had only Ca^{2+}. The individual Ca^{2+} or Mg^{2+} effects were increased by increasing salinity level. The single Ca effects increased soil structure factor values from 69.62 to 76.88%; and the single Mg^{2+} effects increased soil SF values from 62.58 to 81.72% for the five levels of saline irrigation water, respectively. On contrary, the individual Na^{+} effects on soil SF was generally decreased by increasing salinity levels from 64.51 to 57.47% at the five saline irrigation water levels, respectively. These suggest that, leaching of Na^{+} by added 30% of LF was led to an increase in the SF values. It can be noticed that, the SF values were increased with increasing individual or mixed divalent cations i.e., Ca^{2+} or Mg^{2+} in irrigation water, whereas increasing of monovalent cations such as Na^{+} in irrigation water decreased soil SF values. The same conclusion was obtained by El-Maddah (1988), who reported that the structure factor increased with the increases of soluble and exchangeable Ca^{2+} and Mg^{2+}, while it decreased with increasing both soluble and exchangeable Na^{+}.

4. Soil available water

Data presented in Table 4 show that, soil available water (AW) values were decreased by increasing salinity levels. The maximum values were decreased from 23.29 to 16.64% at the five

```
                DATA
             Replicates
        I        II        III
Treatments
   1 69.1900  67.2600  72.4200
   2 63.5800  61.2600  62.9000
   3 63.4800  66.0300  64.0300
   4 66.1300  67.2600  67.4200
   5 62.0600  67.5500  64.6500
   6 65.5200  64.2300  67.1300
   7 59.5200  64.8400  63.3900
   8 63.2900  66.9700  63.2900
   9 67.5800  63.3900  67.9000
  10 66.1300  63.3900  62.2600
  11 64.1300  66.3200  67.5800
  12 66.2900  64.8400  66.4500
  13 66.1300  68.3900  68.5500

 AVERAGE VALUE      :

  69.6233  62.5800  64.5133  66.9367  64.7533  65.6267  62.5833
  64.5167  66.2900  63.9267  66.0100  65.8600  67.6900

COEFF.DITER.= .5933157
  CORRELATION COEFFICINT= .7702699

CRITERION FISHER F( 12.000 26.000) 3.160971
   SOCT= 1.925492
CONTROL 66.01 - 0 = 66.01        t= 46.86537
CONTROL 65.86 - 0 = 65.86        t= 46.75887
CONTROL 67.69 - 64.13001 = 3.55999       t= 2.527499

     69.6233     69.2196     68.7491     68.2117     67.6076     66.9367
     66.1989     65.3944     64.5231     63.5849     62.5800

     68.2789     67.3144     66.4589     65.7123     65.0748     64.5463
     64.1267     63.8162     63.6147     63.5221

     67.1197     65.7702     64.7055     63.9255     63.4304     63.2201
     63.2945     63.6538     64.2979

     66.1457     64.5870     63.4889     62.8513     62.6744     62.9581
     63.7023     64.9072

     65.3569     63.7648     62.8091     62.4897     62.8068     63.7603
     65.3501

     64.7533     63.3036     62.6661     62.8407     63.8276     65.6267

     64.3349     63.2034     63.0599     63.9043     65.7368

     64.1017     63.4642     63.9905     65.6805

     64.0537     64.0860     65.4579

     64.1909     65.0688

     64.5133

Ymax= 69.62334            Ymin= 62.48973
     x1   10   9   9   9   9   9   9   9   9   9   8    x2
             9   9   9   9   9   9   9   9   9   9
               9   9   9   9   9   9   9   9   9
                 9   9   9   9   9   9   9   9
                   9   9   9   8   9   9   9
                     9   9   9   9   9   9
                       9   9   9   9   9
                         9   9   9   9
                           9   9   9
                             9   9
                               9
                               x3
```

Fig. 5. Soil structure factor as affected by all the possible combinations of Ca^{2+}, Mg^{2+} and Na^{+} for saline irrigation water of 1000 ppm.

saline irrigation water levels, as compared with that of control value (23.29%). Similar results was obtained by Kandil (1990) who found that, using of low quality water for irrigation decreased soil available water significantly. The effect of individual cations were generally decreased AW with increasing salinity levels, whereas the individual Ca^{2+} values were ranged between 19.06 and 10.30%; the individual Mg^{2+} values were ranged between 19.62 and 11.11%; and the individual Na^+ values were ranged between 18.71 and 17.93% at the five irrigation water salinity levels. It can be noticed that the individual Na^+ had more pronounced effects than Mg^{2+} or Ca^{2+}.

5. Soil pore size distribution.

Data in Table 4 reveal that the large pores (>9μ) values were sharply decreased with increasing salinity levels. The maximum values were ranged between 34.69 and 24.58% for saline irrigation water levels from 1000 to 10000 ppm respectively. While addition 30% of LF to 10000 ppm treatment lead to an increase of large pores to be 28.78%, compared with that of control value (20.95%). Similar conclusion was obtained by Abdel-Rasheed (1996), who reported that both quickly and slowly drainable pores are decreased when drainage water was used for irrigation. However, the individual Ca^{2+} decreased the large pores values from 30.05 to 27.88, 22.26, 17.78 and 28.78%, respectively, while Mg^{2+} effects, gave the values of 34.69, 23.69, 19.62, 17.56 and 21.19%, respectively. Meanwhile, the individual Na^+ generally increased the large pores values with increasing salinity levels, to be 13.47, 15.05, 16.89, 18.13 and 22.12% at the five saline irrigation water levels, respectively, Table 4. These results suggest that at low salinity level between 1000 and 5000 ppm, most of the formed aggregation were larger than 9μ due to increasing Ca^{2+} or Mg^{2+} of irrigation water, while increasing salinity level of irrigation water up to 5000 ppm leads to increase the formed aggregation larger than 9μ due to the high saline concentration of irrigation water. However, added 30% of LF for saline irrigation water of 10000 ppm, lead to an increase of formed aggregate larger than 9μ due to the presence of Ca^{2+} or Mg^{2+}; and the successive leaching of Na^+.

Regarding to the medium pores (9-0.2μ) values, data reveal that it decreased by increasing salinity levels. However, the individual effect of Na^+ at 10000 ppm was higher than that of Ca^{2+} or Mg^{2+} on their action upon medium pores; this due to high saline concentration of the irrigation water.

Referring to the values of micropores or capillary pores (< 0.2μ), data showed that increasing micropores was occurred by increasing salinity levels. This means that, the most of formed aggregation (due to the soil salinization) were false comparing with the aggregation formed under low salinity of irrigation water. These results are confirmed with that of Abdel-Rasheed (1996).

III. Effect of Different Combinations of Ca^{2+}, Mg^{2+} and Na^+ in Irrigation Water at Different Salinity Levels on Sorghum Plant

1. Total forage yield

The results presented in Table 5 indicate that total forage yield values (green and dry) of Sudan grass were decreased regularly by increasing salinity levels. At low salinity levels, less than 2500 ppm, a regularly increased of both green and dry yields were detected. Increasing salinity level more than 2500 ppm leads to a sharp decrease of both green and dry yields. Similar results was obtained by Sohsah (1992), who reported that a clear augment was detected for green and dry yields at low salinity level (2000 ppm); and such yields decreased regularly by increasing salinity level up to 6000 ppm. This means that, increasing salinity levels of irrigation water lead to an increase of yield reduction percent. Similar results were obtained by Francois *et al.* (1984), who reported that vegetative growth of sorghum plant was depressed to about 50% as compared with the control at both medium and high salinity levels (10 or 20 dSm^{-1}) while grains production decreased at about 35% at medium salinity level (10 dSm^{-1}).

The individual cations effect indicated that, at low salinity level (< 2500 ppm), the increase of Ca^{2+} or Mg^{2+} in the irrigation water leads to an increase of total forage yield. On contrary, the increase of Na^+ in irrigation water leads to a decrease in total forage yield. This means that the effect of divalent cations has positive effects comparing with monovalent cations. The order was as the follows: $Ca^{2+} > Mg^{2+} > Na^+$. At high salinity level (> 2500 ppm), the

Na^+ or Mg^{2+} were more negatively effective than Ca^{2+} on both green and dry yields, the order was as the follows : $Na^+ > Mg^{2+} > Ca^{2+}$. These due to the deleterious effect of Na^+ salts on soil physical properties which caused compact of soil layer and depress water transmission. This may be led to inability of roots to absorb adequate of water and decreasing of plant productivity.

Table 5: Effect of different combinations of Ca^{2+}, Mg^{2+} and Na^+ at different irrigation water salinity levels on total forage yield of Sudan grass

Salinity levels (ppm)	Total green yield* (gm/pot)					Total dry yield* (gm/pot)				
Treat. No.	1000	2500	5000	10000	10000+30 %LF**	1000	2500	5000	10000	10000+30 %LF**
1	221.29	179.04	30.19	12.13	22.49	54.32	45.53	10.56	6.44	11.83
2	212.49	165.78	35.12	13.37	26.83	50.15	43.29	14.03	6.99	13.41
3	154.10	48.04	33.50	14.81	24.64	39.42	16.95	14.46	7.23	12.61
4	211.62	138.91	24.21	14.97	25.25	53.87	36.15	9.65	6.40	11.36
5	199.06	74.93	14.29	12.37	24.40	51.60	21.24	6.94	6.19	11.60
6	169.02	98.74	13.28	6.51	5.86	44.62	26.50	6.13	3.49	3.08
7	206.86	65.98	20.42	18.02	17.00	49.66	19.83	9.11	8.35	7.83
8	183.81	111.16	35.08	10.71	16.38	43.34	28.68	11.87	5.83	8.98
9	192.59	107.62	27.79	8.90	12.33	47.49	29.07	9.95	4.21	5.66
10	193.22	39.92	23.88	9.43	7.54	47.06	13.88	10.25	4.21	3.77
11	202.71	94.04	35.25	11.24	12.89	46.86	24.69	11.95	4.52	6.54
12	220.12	44.97	22.87	10.34	5.30	51.35	12.92	8.80	4.48	3.04
13	174.55	43.21	22.86	7.92	5.52	39.13	11.47	7.68	3.20	2.95
Control	220.74					58.86				

* Summation of the four cuts, green and dry yields ** LF = leaching fraction

2. Proline content in plant.

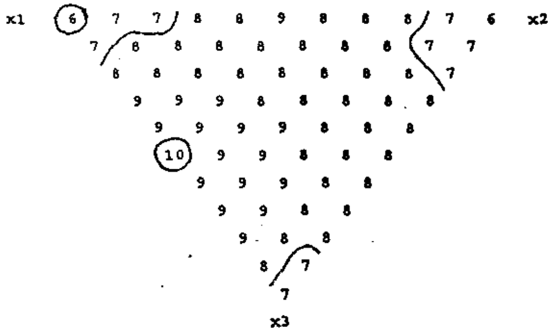
Data presented in Table 6 and Figs. 6 and 7 show that amino acid proline was gradually increased with increasing salinity levels from 1000 to 10000 ppm. While addition 30% of LF to saline irrigation water of 10000 ppm caused a decrease of proline content but the values still higher than under 2500 ppm. Similar result was obtained by Khodary (1992), who reported that the proline content of Sudan grass was progressive increased with increasing salinity levels.

Table 6: Mean values of free proline content (µ mol /g dry matter) in different successive cuts of Sudan grass grown under different salinity levels and Ca^{2+}, Mg^{2+} and Na^{+} combinations in irrigation water

linity level ppm	1000				2500				5000				10000				10000+30% LF			
Cuts																				
Treat. No.	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1	29.58	22.29	36.84	12.96	57.21	24.65	42.26	29.26	74.57	25.34	44.59	–	82.17	–	–	–	65.65	–	–	–
2	30.56	23.42	37.12	15.41	63.51	26.71	39.05	25.76	71.45	27.63	45.68	–	83.67	–	–	–	60.80	25.82	–	–
3	34.41	23.61	38.03	20.85	64.81	24.85	–	–	74.32	26.96	–	–	88.81	–	–	–	76.18	–	–	–
4	43.44	32.16	31.15	12.99	56.96	35.53	34.70	29.65	66.39	39.14	–	–	71.60	–	–	–	68.75	–	–	–
5	47.92	30.88	31.72	18.78	59.26	33.98	36.96	–	69.79	–	–	–	79.11	–	–	–	70.35	–	–	–
6	42.36	33.90	32.11	19.59	56.70	34.78	36.72	–	61.68	–	–	–	64.68	–	–	–	61.84	–	–	–
7	42.89	27.32	35.00	12.19	49.21	29.86	39.88	–	62.44	–	–	–	77.77	–	–	–	63.60	–	–	–
8	44.37	27.44	31.72	18.75	49.32	30.05	36.42	27.45	61.54	31.06	–	–	68.61	–	–	–	56.44	–	–	–
9	39.19	20.73	33.24	15.15	43.26	22.41	–	–	68.58	25.67	37.77	–	74.08	–	–	–	58.14	–	–	–
10	41.30	29.88	32.73	16.77	50.98	31.14	38.09	–	54.01	–	–	–	63.00	–	–	–	55.85	–	–	–
11	45.51	24.89	33.13	18.52	60.08	25.87	39.45	–	66.80	30.00	44.45	–	73.41	32.63	–	–	68.87	–	–	–
12	39.93	20.22	31.10	15.34	54.74	24.63	–	–	60.13	26.66	–	–	61.13	30.87	–	–	60.72	–	–	–
13	47.48	23.27	32.92	17.05	61.94	25.69	–	–	64.56	27.56	–	–	72.96	–	–	–	62.39	–	–	–
Control	27.88	14.84	27.80	9.03																

LF = leaching fraction

```
                 DATA
               Replicates
         I         II        III

    1  30.1200   29.0500   29.5800
    2  30.9900   30.4800   30.2100
    3  35.4100   33.4100   34.4100
    4  44.6400   43.4400   42.2400
 T  5  47.1700   47.9200   48.6800
 r  6  42.2900   42.3600   42.4300
 e  7  42.7000   42.8900   43.0900
 a  8  45.8000   44.3700   42.9500
 t  9  39.7800   39.1900   38.6100
 m 10  40.3900   41.3000   42.2200
 e 11  47.7300   45.4100   43.4000
 n 12  40.5200   38.5100   40.7500
 t 13  48.2000   47.4800   46.7700
 s
 AVERAGE VALUE      :

   29.5833  30.5600  34.4100  43.4400  47.9233  42.3600  42.8933
   44.3733  39.1933  41.3033  45.5133  39.9267  47.4833

 COEFF.DITER.= .9790771
   CORRELATION COEFFICINT= .9894832

 CRITERION FISHER F( 12.000 26.000) 101.3881
    SOCT= 1.016586
 CONTROL 45.51334 - 0 = 45.51334       t= 61.20381
 CONTROL 39.92667 - 0 = 39.92667       t= 53.69117
 CONTROL 47.48334 - 42.79445 = 4.688885      t= 6.305353

      29.5833      34.4936      38.3344      41.1057      42.8076      43.4400
      43.0029      41.4964      38.9204      35.2749      30.5600

      35.7996      38.6299      40.7165      42.0594      42.6587      42.5143
      41.6262      39.9945      37.6191      34.5000

      40.7417      41.8178      42.4760      42.7163      42.5388      41.9434
      40.9301      39.4990      37.6500

      44.4097      44.0574      43.6130      43.0765      42.4480      41.7274
      40.9147      40.0100

      46.8036      45.3487      44.1275      43.1400      42.3863      41.8663
      41.5800

      47.9233      45.6916      44.0194      42.9067      42.3536      42.3600

      47.7689      45.0862      43.2888      42.3767      42.3500

      46.3404      43.5325      41.9357      41.5500

      43.6377      41.0304      39.9600

      39.6609      37.5800

      34.4100

 Ymax= 47.92333              Ymin= 29.58334
```



```
       x1   6   7   7   8   8   9   8   8   8   7   6   x2
              7   8   8   8   8   8   8   8   7   7
                8   8   8   8   8   8   8   8   7
                  9   9   9   8   8   8   8   8
                    9   9   9   9   8   8   8
                     10   9   9   8   8   8
                        9   9   9   8   8
                          9   9   8   8
                            9   8   8
                              8   7
                                7
                                x3
```

Fig. 6. Free praline content (µ mol/g dry matter) of Sudan grass as affected by all the possible combinations of Ca^{2+}, Mg^{2+} and Na^{+} for saline irrigation water of 1000 ppm at the 1st cut.

```
                DATA
              Replicates
        I          II         III
Treatments
 1 82.0400   83.5700   80.9000
 2 81.5200   83.6700   85.8200
 3 88.8100   87.1100   90.5100
 4 70.3300   71.6000   72.8700
 5 80.1400   79.0200   78.1700
 6 64.1600   64.6800   65.2100
 7 77.3400   79.0300   76.9500
 8  0.0000   69.4400   67.7700
 9 73.1300   75.5600   73.5600
10 61.3400   65.3400   62.3100
11 72.9300   73.4100   73.8900
12 61.6800   60.5900   61.1300
13 72.2100   73.7100   72.9600

 AVERAGE  VALUE      :

   82.1700   83.6700   88.8100   71.6000   79.1100   64.6833   77.7733
   45.7367   74.0833   62.9967   73.4100   61.1333   72.9600

 COEFF.DITER.= .5947193
   CORRELATION COEFFICINT= .7711805

 CRITERION FISHER F( 12.000 26.000) 3.179422
    SOCT= 11.05965
 CONTROL 73.41 - 0 = 73.41        t= 9.073978
 CONTROL 61.13334 - 0 = 61.13334       t= 7.556499
 CONTROL 72.96 - 68.37037 = 4.58963        t= .5673097

      82.1700       78.2448       75.2252       73.1112       71.9028       71.6000
      72.2028       73.7112       76.1252       79.4448       83.6700

      80.5372       78.6906       77.1914       76.0396       75.2351       74.7781
      74.6684       74.9061       75.4912       76.4236

      79.4148       79.0886       78.5516       77.8037       76.8450      .75.6754
      74.2950       72.7038       70.9017

      78.8028       79.4388       79.3057       78.4036       76.7324       74.2921
      71.0828       67.1044

      78.7012       79.7411       79.4538       77.8392       74.8973       70.6281
      65.0316

      79.1100       79.9957       78.9958       76.1105       71.3397       64.6833

      80.0292       80.2024       77.9318       73.2176       66.0596

      81.4588       80.3613       76.2618       69.1604

      83.3988       80.4723       73.9857

      85.8492       80.5356

      88.8100

Ymax= 88.81          Ymin= 64.68333

     x1    9   8   8   8   8   8   8   8   8   8   9   x2
             9   8   8   8   8   8   8   8   8   8
               8   8   8   8   8   8   8   8   7
                 8   8   8   8   8   8   8   7
                   8   8   8   8   8   7   7
                     8   9   8   8   8   7
                       9   9   8   8   7
                         9   9   8   7
                           9   9   8
                             9   9
                              10
                               x3
```

Fig. 7. Free praline content (µ mol/g dry matter) of Sudan grass as affected by all the possible combinations of Ca^{2+}, Mg^{2+} and Na^{+} for saline irrigation water of 10000 ppm at the 1st cut.

Regarding to the single cations effect, data indicate that increasing Na^+ in irrigation water up to 100% lead to an increase of proline accumulation in Sorghum plant tissues by increasing salinity levels from 1000 to 10000 ppm, compared to the other two cations (Ca^{2+} and Mg^{2+}). These means that Na^+ was more effective than Mg^{2+} or Ca^{2+} on plant amino acid proline content, meanwhile the Mg^{2+} or Ca^{2+} effects were nearly equal, and take the following order: $Na^+ > Mg^{2+} > Ca^{2+}$. However, at low salinity level (1000 ppm) proline accumulation in Sorghum plant tissues, Fig. 6, may be due to the effect of specific ion toxicity. The effect of Na^+ was higher than that of Mg^{2+} or Ca^{2+}. Increasing salinity levels up to 10000 ppm, Fig. 7 revealed that proline accumulation in plant may be due to the high osmotic pressure of the root media.

However, the amino acid proline is considered as one of the major source of energy during water stress and may act as an osmotic regulator during salinity stress. This conclusion was in agreement with Sohsah (1992).

REFERENCES

Abd El-Nour,A.S. 1989. The interaction effects of salty water and fertilization on soil physical and chemical properties, yields and water consumptive use of plants grown in different Egyptian soils. Ph.D. Thesis, Fac. of Agric., Ain Shams Univ., Egypt.

Abdel-Rasheed,A. 1996. Long-term effect of irrigation by low-water qualities on soil properties and productivity. M.Sc. Thesis, Fac. of Agric., Ain Shams Univ., Egypt.

Abo El-Defan,T.A. 1990. Effect of organic manures on plant growth and nutrients uptake under saline condition. Ph.D. Thesis, pp. 56-181. Fac. of Agric., Ain Shams Univ., Egypt.

Alawi, B.J., L.L. Stroehlein, A.E. Hanlon and F. Turner 1980. Quality of irrigation water and effects of sulphuric acid and gypsum on soil properties and Sudan grass yields. Soil Sci., 129, 315-319.

Babcock, K. L., R.M. Carlson, R.K. Schulz and R. Overstreet 1959. A study of the effect of the irrigation water composition on soil properties. Hilgardia, 29:155-164.

Bates, L. S. 1973. Rapid determination of free proline for water-stress studies. Plant and Soil.39:205-207.

Black, C. A. 1965. Methods of soil analysis. Part I. Physical and Mineralogical properties, including statistics of measurements and sampling. Amer. Soc. of Agronomy, Inc. Publisher Madison, Winconsin , USA, pp. 213-377.

Cottenie, A. 1980. Soils and plant testing as a basis of fertilizer recommendation. FAO, Soil Bull., 3812.

El-Maddah, El-H. 1988. Effect of some salt solutions, Polymer and organic matter on soil structure and some other soil properties. M.Sc. Thesis, Fac. of Agric., Alexandria Univ., Egypt.

FAO 1992. The use of saline waters for crop production. Irrigation and Drainage Paper, No. 48, Rome 1992.

Francois, L. E.; T. Donovan and E. V. Mass 1984. Salinity effects on seed yield, growth and germination of grain sorghum. Agron. J., 76:741-744.

Gupta, I. C. 1980. Crop response to boron in soil irrigated with high boron waters. Ann. Rep. CSSRI, Karnal.

Kandil, N. F. 1990. Effect of using Drainage water on Soil Physical Chemical & Hydrological Properties in some soil of Egypt. Ph.D. Thesis, Cairo Univ., Egypt.

Khodary, S. E. 1992. Effect of salinity and tryptophan on growth and some metabolic changes in wheat and sorghum plants. Biologia Plant. 34:436-443.

Lima, L. A. and M.E. Grismer 1992. Soil crack morphology and soil salinity. Soil Sci., 153:2, 149-153.

Mostafa, M. A. , M. A. El-Toni and A. A. Sakr 1988. Soil hydraulic conductivity as affected by constituents of different saline solutions. In Proceedings of the second conference of the agricultural development research Cairo. 17-19 Dec. 1988. Vol. IV. Soils Dep. Ain Shams Univ., Egypt.

Moussa, K. F. 1987. A computer model on suitability of irrigation water. Egypt J. Appl. Sci., Fac. of Agric., Zagazig Univ., Second Issue June (2), 892-879.

Moussa, K. F. 1991. Evaluation of the relative affinities of exchangeable cation in the âluvial soil of El-Sharkiya governorate. Zagazig J. Agric. Res. Vol. 18 (4), 1151-1160.

Page, A. L., R.H. Miller and D.R. Keeney 1982. Methods of soil analysis part 2. Chemical and microbiological properties. Second Edition. Madison, Wisconsin USA.

Puntamkar, S. S., K. Kant and S.K. Mathur 1988. Effects of saline water irrigation on soil properties. Transactions of Indian, Soc. of Desert Technology, 2, pp. 69-72.

Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils, U.S. Salinity laboratory Staff. Agriculture Handbook, No. 60.

Sohsah, S. M. Z. 1992. Studies on the adaptive responses of some plants to salinity. Ph.D. Thesis, Fac. of Sci., Al-Azhar Univ. (Girls Branch), Cairo, Egypt.

Yadav, J. S. P. 1978. Effect of saline irrigation water on soil and crop growth. Agrokem. Talojtan 26, 19-28. (C.F. Soils and Fert. Vol. 41 No. 1978).

تأثير جودة مياة الري علي بعض خواص التربة ونبات السورجم

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أجريت تجربة أصص في محطة البحوث الزراعية بالجميزة محافظة الغربية. أخذت عينات ارض طينية طميية لدراسة تأثير مستويات الملوحة المختلفة لمياة الري علي بعض خصائص التربة ومحصول حشيشة السودان. استخدمت ثلاثة عشر معاملة لماء الري لكي تغطي كل التداخلات الممكنة لأملاح الكالسيوم والماغنسيوم والصوديوم في ماء الري عند مستويات ملوحة مختلفة. وقد أخذت أربع حشات من نبات حشيشة السودان خلال موسم النمو الذي استمر ١٦٥ يوم. ويمكن تلخيص النتائج المتحصل عليها كالتالي :

١- زادت قيم رقم حموضة التربة، التوصيل الكهربي، وايونات كا$^{++}$، مغ$^{++}$، ص$^{+}$ المتبادلة، الكثافة الظاهرية للتربة، التوصيل الهيدروليكي للتربة، معامل بناء التربة، ومحتوى رطوبة التربة وكذلك المسام الشعرية للتربة. بينما انخفضت قيم نسبة تشبع التربة، الماء الميسر، والمسام الكبيرة والمتوسطة بزيادة مستويات الملوحة رغم عدم وجود اختلافات واسعة بين المعاملات الثلاثة عشر الأصلية.

٢- زادت قيمة محتوى النبات من البرولين بزيادة مستويات الملوحة. بينما انخفضت قيم محصول العلف الكلي (الأخضر والجاف) بزيادة مستويات الملوحة.