The Effects of Irrigation Water Salinity, Potassium Nitrate Fertilization, Proline Spraying and Leaching Fraction on the Growth and Chemical Composition of Corn Grown in Calcareous Soil

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ABSTRACT

Two pot experiments were conducted to study the effect of irrigation with saline water in relation to KNO_3 fertilization, proline spraying and leaching fraction on the growth and Na^+, K^+, Cl^-, NO_3^- and proline contents of corn (*Zea mays* L.) plant grown on a nonsaline calcareous soil. The treatments included irrigation waters of different salinity (0.54, 3.36, 5.88 or 7.95 dS/m), three rates of KNO_3 (0, 4 and 8 g/pot) fertilizer and foliar application with three rates of proline (0, 100 and 200 mg/L). The first experiment was irrigated with the water to the field capacity with leaching fraction and the second without leaching fraction. The experimental design was a split split plot with three replications. Also, the effect of these parameters on salt accumulation in soil was discussed. The obtained results showed that the dry weight of shoots was decreased as salinity of irrigation water increased. The highest decreases were attained with waters of 5.88 and 7.95 dS/m as compared with dry weight due to irrigation with 0.54 or 3.36 dS/m water salinity. High salinity of water increased the shoot contents of Na^+, Cl^-, proline and decreased NO_3^- contents with or without leaching fraction, but the values without leaching fraction were higher than those of without leaching fraction. Also, increasing the salinity of irrigation water decreased K content in shoot which was higher with leaching than without leaching. On the other hand, KNO_3 fertilization or proline spraying decreased Na^+, Cl^- contents and increased K^+ or NO_3^- contents in plant shoot and their values without leaching were higher than with leaching. The EC values of soil were increased with both increasing salinity of irrigation water and KNO_3 fertilization. The decreased plant growth due to water salinity was partially offset by KNO_3 fertilization, proline spraying and leaching fraction application. Also, KNO_3 fertilization was more effective than proline for reducing the adverse effect of water salinity.

Key words: Water salinity ,potassium nitrate, proline , leaching fraction , fertilization.

INTRODUCTION

The utilization of various sources of water is necessary in Egypt due to increasing population and the consequent need of agricultural expansion. The main problem to be considered in using the different sources of water is the salinity hazards. Soil salinity is being progressively exacerbated by agronomic practices such as irrigation and fertilization, especially in arid regions. The effect of salinity on plant growth may be more related to the Na^+/K^+ ratio of the plant tissue than to absolute Na^+ concentrations. Thus the cultivars which have an ability to minimize this ratio may be more salt tolerant than those with lower K^+ concentration (Benzyl and Reuveni, 1994; Lingle, *et al*., 2000). Application of K improved growth and yield under water stress possibly by regulating photosynthesis (Gupta *et al*., 1989). Also, the plant growth may be related to Cl/NO_3 ratio in the plant tissue. There is ample evidence of root absorption competition between Cl and NO_3 for plants (Kafkafi *et al*., 1982; Savvas and Lenz, 1996; Fisarekis *et al*., 2001) and the inhibition of NO_3 uptake might occur by Cl. Plants which are dependent upon KNO_3 as a source of N are less sensitive to salt stress (Singleton and Bohlool, 1984).

Proline accumulation has been shown to be fast, and is thought to function in salt stress adaptation (Berteli *et al.,* 1995), through protection of plant tissue against osmotic stress and/or acting as enzyme protector (Solomon *et al.,* 1994; Liu and Zhu, 1997). Accumulation of proline in plants under stress may offer multiple benefits to the cell. Hong *et al.,* (2000) showed that free radicals are formed during osmotic stress, as measured by an increase in the malondialdehyde production. They also recorded that transgenic plants, which produce more proline, accumulate less malondialdehyde. It was concluded that Na^+ exclusion from the shoot was not correlated with salt tolerance and that free proline and glycinebetaine accumulation in the shoot was a possible indicator for salt tolerance in the maize genotypes studied (Mansour *et al*., 2005). Leaching is the key factor in controlling soluble salts in soils brought in by irrigation water. The amount of leaching required depends upon crop, salinity of water, soil characteristics, climate and management (Hoffman, 1990).

The objective of the present study was to determine the possibility of compensating the negative effect of irrigation water salinity by foliar application the plants with proline, potassium nitrate fertilization and leaching fraction application, on both the growth and chemical composition of corn plants and the salt accumulation in soil.

MATERIALS and METHODS

Pot experiments were carried out in the greenhouse of Faculty of Agriculture Saba Basha, Alex. Univ. using a calcareous soil (typical calciorthids). The main chemichal and physical characteristics of this soil was determined according to the methods outlined by Black (1965) and the obtained data are presented in Table 1. Four different qualities of irrigation water were used. The first one (S1) was tap water and the other three (S2, S3 and S4) were prepared by blending tap water with sea water. The main chemical compositions of these waters are given in Table 2. In this study, two experiments were carried out. The first one included leaching fraction application. This fraction was calculated (Rhoades and Merrill, 1976) for corn at 90% yield potential according to the salinity of irrigation water. The desired leaching fraction was added to the amount of water required to keep the soil moisture content at field capacity. The second experiment was carried out without applying the leaching fraction.

Experimental Layout: Ten Kgs air-dried soil were placed inside a plastic pot (25 cm in diameter and 30 cm depth) with a hole in its bottom for drainage. The soil in each pot was irrigated with tap water before planting the seeds of corn to achieve suitable seeding medium. The experimental design was a split split plot with three replicates. The water quality treatments were arranged at random in the main plots and three levels of potassium nitrate fertilizer (0, 4 and 8 gm/pot) were applied and arranged at random in the sub-plots. Each amount of this fertilizer was divided into three equal parts and applied during plant growth period (before sowing, after 3 and 5 weeks from sowing). Three levels of proline ($C_5H_9NO_2$) (zero, 100 and 200 mg/L) were applied as foliar and arranged at random within the sub-sub-plots. Superphosphate fertilizer was applied and mixed with the soil in each pot before planting at a rate of 2 g/pot and N as ammonium nitrate fertilizer at a rate of 1.5 g/pot was applied in two equal doses, before and after plant thinning. Five seeds of corn (*Zea mays* L.) cultivar S.C.10 were planted in each pot and irrigated with tap water. After 21 days from sowing, the plants were thinned to 2 uniform plants per pot. Irrigation treatments were applied, when the soil moisture content had reached 75% of the soil field capacity, to raise soil moisture content to the field capacity. The proline treatments were foliar applied, after adding "Tween 20" (0.05 %) as a wetting agent, using hand atomizer after 28 and 35 days from plant sowing.

Plant and Soil Sampling and Analysis: The plant shoots were collected after 60 days from planting, washed with tap water then by distilled water, dried in an oven at 65˚C for 48 hours and the dry weights were recorded. Sub-samples of plants were ground using stainless steal mill. The oven dried plant material was wet digested and the concentrations of Na, K were determined (Chapman and Pratt, 1961). In addition, the concentrations of Cl and NO_3 were determined according to the methods outlined by Chapman and Pratt (1961) and by Cataldo *et al*. (1975). The proline content in plant leaves was determined according to the method of Bates *et al*. (1973). After plant harvest, soil samples were collected from each pot and their salinity were determined (Black 1965). All data were statistically analyzed according to Gomez and Gomez (1984). The regression analysis was carried out by CoHort Software (1995).

RESULTS and DISCUTION

Shoot Dry Weight:

Table 3 showed that the corn shoots of plant dry weight was markedly decreased from 6.44 g/pot with water salinity of 0.54 dS/m to 6.36 g/pot with water salinity of 3.36 dS/m. However, with increasing water salinity to 5.88 and 7.95 dS/m, there were significant decreases of plant dry weights with or without leaching treatment. In this concern, it has been reported that salinity of 3.6 dS/m is water salinity marginal for corn production (Ayres and Westcot, 1985). It is also clear that the dry weight of corn plant had decreased significantly from 6.00 g/pot to 2.64 g/pot with increasing water salinity from 0.54 to 7.95 dS/m without leaching fraction treatment. These results clearly showed that applying leaching fraction at any salinity level had decreased the harmful effect of salinity of irrigation water especially at water salinity of 3.36 dS/m which is less than 3.60 dS/m, the marginal value of corn production according to Ayres and Westcot (1985). It is also clear that the harmful effect of salinity was greater in the treatment of without leaching. This is due to the accumulation of salts in the root zone, which did not occur with using the leaching fraction. Similar results have been also reported by Gendy and Hammed (1993), Radwan *et al.* (1993) and Abou Hussien *et al.*, (1994).

Table 3 and Fig 1 indicated a significant increase in the dry weight of corn plants, with or without leaching treatment, due to applying potassium nitrate fertilizer up to 8 g /pot. The relative increases in plant dry weights with potassium nitrate application (4 and 8 g/pot), and without leaching were 6.7 and 11.96% and with leaching were 2.57 and 5.94%, respectively. These data indicate the beneficial effect of appling potassium nitrate fertilizer for decreasing the harmful effect of salinity on plant growth. This is evident for plants grown without leaching treatment than with leaching treatment. Similar results were found by Badr and Shafei (2002) who reported that increasing K^+ application could be useful to overcome the adverse effect of salinity (NaCl) on the growth of wheat plant. It can be stated that the ability of plants to retain K^+ at high Na^+ concentration, of the external solution, may be involved in reducing the damage associated with excessive Na^+ concentration in plant tissue. In addition, the presence of N in the form of KNO_3 at this saline condition had improved the growth of corn plant. This was also found by Martinez and Cerda (1989) who indicated that increasing NO_3^- in the substrate decreased Cl^- uptake and accumulation in plant tissue which had improved the growth of tomato and cucumber plants grown in saline conditions. Table (3) and Fig 2 revealed that foliar application of proline increased significantly the dry weight of plant shoots, with or without leaching treatment. Foliar application of 100 or 200 mg proline /L increased the relative dry weight, without leaching treatment, to values of 2.06 and 3.67%, respectively while with leaching treatment these values were 1.17 and 2.33%, respectively. This points out that foliar application of proline (200 mg/L) significantly decreased the harmful effects of salinity with or without leaching treatment.The interaction effect between salinity of irrigation water(S) and potassium nitrate (K) on shoots dry weight, with or without leaching treatment, was highly significant (Table 3). The maximum dry weights with or without leaching were obtained with KNO_3 treatment of 8 g/pot, with each level of salinity of irrigation water. There was also a significant interaction effect between salinity of irrigation water and proline (S x P) on the dry weight of plant without leaching treatment only. The highest values of dry weight, without leaching treatment, were obtained when the plant was sprayed with 200 mg/L proline at each level of irrigation water salinity.

Multiple regression analysis between the dry weight (Y), KNO_3 (X_1) and proline (X_2), with or without leaching, are presented in Table 4. This relation showed that the dry weight was positively correlated with these two variables. The slope of each variable, in the equation, gives a quantitative expression of the efficiency of KNO_3 and proline for reducing the adverse effect of salinity. As a result, KNO_3 fertilizer showed higher efficiency for reducing the adverse effect of salinity on plant growth than proline.

Chemical Composition of Plants

Table 5 and Fig 3 showed that sodium concentration in the shoot of corn plant increased significantly from 0.41 % with irrigation by water of 0.54 dS/m to 1.07 % with irrigation by water of 7.95 dS/m, with or without leaching treatment. On the other hand, K^+ concentration in plant shoot decreased from 4.71 % to 1.82 %, with same treatment respectively. These results are associated with increasing Na/K ratio in plant from 0.09 to 0.58, respectively. Similar results were obtained by Santos *et al.* (1999) who reported that salinity decreased K^+ content in plants. On the other hand, applying KNO_3 fertilizer significantly decreased Na^+ and significantly increased K^+ concentrations in the shoot of corn plant, with or without leaching treatment. This increase of K^+ content had improved the Na – K balance in plant tissue which facilated plant growth as indicated in Table 3 and Figs 3, 4, 5 and 6. Foliar application of proline decreased the concentration of Na^+ in plant shoot. At the highest level of proline (200 mg/L), the relative decrease of Na^+ was 7.79 and 6.19% with or without leaching, respectively. In the same time, K^+ contents in shoot were increased and their relative increases were 4.73 and 6.52 %, respectively. Close results were obtained by Shaddad (1990) with *Raphanus sativus* grown under salinity stress.

Irrigation with 7.95 dS/m saline water produced the highest Na/K ratio with or without leaching (0.58 and 0.78, respectively). Similar results were found by Badr and Shafei (2002) who confirmed that decreasing the value of Na/K ratio may be involved in reducing the damage associated with excessive Na^+ levels in plant. It is clear from Table 5 that the Na/K ratio, with or without leaching, was decreased significantly with increasing KNO_3 fertilization. This relation was associated with increasing the dry weight of plant shoot. This points out to the beneficial effect of K^+ to overcome the adverse effects of salinity. The occurrence of high K^+ in plant had involved in reducing the damage caused by high Na^+ concentration. Table 5 also, showed that foliar application of proline decreased the Na/K ratio in plant shoot with or without leaching and this ratio was higher in plant grown without leaching than with leaching treatment. Highly significant negative correlation coefficients were found between dry weights and Na^+ contents in shoots of plant with or without leaching (r = -0.926** and -0.974** respectively). The corresponding correlations for Na/K ratio were -0.95** and -0.968**. On the other hand, highly significant positive correlation coefficients were found between shoot dry weights and K^+ contents in plant, with or without leaching treatment(r = 0.772** and 0.904** respectively).

Increasing salinity of irrigation water significantly increased Cl^- content and decreased NO_3^- contents in the shoot of corn plant (Table 6 and Figs 7, 8, 9 and 10). This decrease in NO_3^- content can be attributed to Cl^- competition with NO_3^- for binding sites on the plasma membrane which suppressed the influx of NO_3^- from the external solution (Balki and Padole, 1982 and Al-Uqaili, 2003). The ratio of Cl^-/NO_3^- in plant tissue increased with increasing salinity of irrigation water and was higher with leaching than without leaching treatment. This is due to low level of NO_3^- in plant tissue, with leaching treatment as compared without leaching. In the same time, proline contents in shoots significantly increased with increasing irrigation water salinity and were higher in plants grown without leaching than with leaching treatment (Table 6 and Figs. 11 and 12). It is clear that there were positive relations between proline contents in plant tissue and both Cl^- contents and Cl^-/NO_3^- ratio. It is also clear from Table (6) that chloride content decreased significantly with increasing KNO_3 application while NO_3^- content increased significantly with or without leaching. Foliar application of corn plant with proline significantly decreased Cl^- contents and increased NO_3^- contents in shoot with or without leaching treatment (Table 6). This could be due to the role of proline in minimizing the adverse effect of salinity which is associated with the decrease of both Na^+ content (Table 5) and Cl^- content (Table 6) and increase of both K^+ content (Table 5) and NO_3^- content (Table 6) in shoots (Figs 3, 4, 5, 6, 7, 8, 9 and 10). This effect was more pronounced with leaching than without leaching treatment. On the other hand, proline foliar application increased significantly NO_3^- contents in shoots and consequently decreased Cl^-/NO_3 ratio.

The interaction effects between irrigation water salinity and potassium nitrate fertilizerwere significant on K^+ and NO_3^- contents with leaching and on NO_3^- contents without leaching. Also, the interaction effects between irrigation water salinity and foliar application with proline were significant with Cl^- contents with leaching, and with NO_3^- contents without leaching. The interaction effect between potassium nitrate and proline was significant on NO_3^- content, with or without leaching. Several studies reported data indicated that increasing NO_3^- in the substrate decreased Cl^- content and its accumulation in plant (Bernstein *et al.*, 1974; Kafkafi *et al.*, 1982; Feigin *et al.*, 1987 and Martinez and Cerda, 1989). However, Cl^-/NO_3^- ratio were decreased significantly with increasing potassium nitrate with or without leaching. The same trend was found with increasing foliar application with proline. The highest values of Cl^-/NO_3^- ratio, with and without leaching (20.82 and 11.42), were found without proline spraying. This indicates that proline application could act well for reducing the accumulation of Na^+ and Cl^- in plant shoots.

Table (6) showed that proline content in plant significantly increased with increasing salinity of irrigation water and significantly decreased with increasing potassium nitrate, with or without leaching (Table 6 and Fig 11). It is obvious that proline plays an adaptive role in the tolerance of plant cells to salinity by increasing the concentration of osmotic active components in order to equalize the osmotic potential of the cytoplasm (Watad *et al.*, 1983). Anjum *et al.* (2005) also found that proline accumulation in the leaves of plants grown on salt affected soil was 8 times higher than in the control. Increasing levels of application foliar with proline significantly increased proline contents in the shoot of corn plant. The relative increases in proline content of corn plants, at 200 mg/L proline, were 103.16 and 72.41% with or without leaching treatment, respectively. Therefore, it can be pointed out that exogenous proline application might counteract the negative effects of high salinity on carbohydrate and nitrogen metabolism which consequently could promote the whole plant growth.

Salinity Build up in Soil

Table 7 showed that the salinity of soil increased significantly with increasing salinity of irrigation water, with or without leaching. This is due to the accumulation of salts in the soil from water of irrigation. Similar results were obtained by Hussan (1981) and Tomar and Yadev (1992) who found significant increases in soil EC when soil was irrigated with highly saline water. Also, EC values in soil were increased significantly with increasing application of KNO_3 fertilizer, with or without leaching (Table 7). Table 7 showed significant interaction effects between irrigation water salinity and potassium nitrate on the EC of soil, with or without leaching. It is clear, that the leaching fraction was effective in reducing the accumulation of salts in soil.

The EC (Y) values of soil, with or without leaching, were regressed against salinity of irrigation water (X_1), potassium nitrate levels (X_2) and proline levels (X_3). The data revealed that the EC of soil was positively correlated with (X_1) and (X_2), and negatively correlated with (X_3), with or without leaching. The multiple regression equations for these relationships were:

With leaching $$Y = -1.17 + 0.77\ X_1 + 0.27X_2 - 0.0001\ X_3$$

$$R^2 = 0.842 \qquad (P < 0.01)$$

Without leaching $$Y = -2.16 + 1.02\ X_1 + 0.043\ X_2 + 0.0001\ X_3$$

$$R^2 = 0.794 \quad (P < 0.01)$$

The comparison of the slopes of each variable in the equation with leaching (0.77: 0.27: 0.0001) and without leaching (1.02: 0.043: 0.0001) gives quantitative estimate for the efficiency of each variable to the other.

In conclusion, the present study confirms the potential of foliar application with proline, soil application with potassium nitrate and leaching fraction treatment for improving the growth of corn under irrigation with saline water, especially at water salinity of 3.36 dS/m, which is less than the marginal value (3.6 dS/m) for corn production. Also, potassium nitrate fertilizer as a source for K and N had more adverse effects, due to salinity, on both plant and soil.

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Table 1. The main chemical and physical characteristics of the used soil.

Soil properties	value	Soil properties	value
pH*	8.2	**Particle size distribution**	
EC** (dS/m)	2.44	Sand (%)	63.1
Total $CaCO_3$ (%)	30.7	Silt (%)	15.2
O.C. (%)	0.34	Clay (%)	21.6
Field capacity (%)	16.0	Soil texture	Sandy Clay Loam

* In 1:2.5 soil water suspension ** In saturation paste extract

Table 2. Chemical composition of the irrigation waters.

Water quality	pH	EC_w dS/m	Cations, meq/L				Anions, meq/L			SAR
			Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HCO_3	
S1	7.98	0.54	1.83	1.07	1.60	0.55	1.50	2.46	0.63	1.33
S2	7.94	3.36	2.15	4.72	23.78	0.42	26.53	6.14	0.22	12.84
S3	7.84	5.88	4.57	8.63	39.27	0.78	44.67	11.63	0.34	15.29
S4	7.72	7.95	6.96	11.94	52.83	0.86	57.72	16.84	0.46	17.19

Table 3. Effect of irrigation water salinity, Potassium nitrate and proline on the mean dry weight of corn plants grown in soil with or without leaching.

Treatment	with leaching	without leaching
	Dry weight (g/pot)	
salinity of irrigation water (S), dS/m		
0.54	6.44	6.00
3.36	6.36	5.05
5.88	4.90	4.08
7.95	3.08	2.64
L.S.D $_{0.05}$	0.24	0.14
Potassium nitrate (K), g/pot		
0	5.05	4.18
4	5.18	4.46
8	5.35	4.68
L.S.D $_{0.05}$	0.05	0.10
Proline (P), mg/L		
0	5.14	4.36
100	5.20	4.45
200	5.26	4.52
L.S.D $_{0.05}$	0.05	0.04
Interactions		
S x K	N.S	0.19
S x P	N.S	0.08
K x P	N.S	N.S
S x K x P	N.S	N.S

Table 4. The multiple regression equations between dry weight (Y), potassium nitrate (X_1) and proline (X2) with irrigation water salinity.

salinity of irrigation Water (dS/m)	With leaching	R^2	Without leaching	R^2
0.54	$Y = 6.19 + 0.043 X_1 + 0.0008 X_2$	0.960	$Y = 5.47 + 0.096 X_1 + 0.0015 X_2$	0.983
3.36	$Y = 6.09 + 0.043 X_1 + 0.0010 X_2$	0.961	$Y = 4.64 + 0.076 X_1 + 0.0010 X_2$	0.994
5.88	$Y = 4.71 + 0.039 X_1 + 0.0004 X_2$	0.991	$Y = 3.86 + 0.042 X_1 + 0.0006 X_2$	0.992
7.95	$Y = 2.95 + 0.025 X_1 + 0.0003 X_2$	0.997	$Y = 2.47 + 0.035 X_1 + 0.0004 X_2$	0.980

Table 5. Effect of irrigation water salinity and potassium nitrate and proline with or without leaching, on the mean value of Na, K concentrations (%) and Na/K ratio in shoot of corn plants.

Treatment	With leaching			Without leaching		
	Na^+	K^+	Na/K	Na^+	K^+	Na/K
salinity of irrigation water (S), dS/m						
0.54	0.41	4.71	0.09	0.51	4.43	0.12
3.36	0.63	3.33	0.19	0.85	3.17	0.27
5.88	0.85	2.26	0.38	1.07	2.13	0.51
7.95	1.07	1.85	0.58	1.32	1.72	0.78
$L.S.D_{0.05}$	0.03	0.22	0.01	0.050	0.46	0.01
Potassium nitrate (K) , g/pot						
0	0.83	2.42	0.39	1.04	2.28	0.52
4	0.74	3.08	0.31	0.94	2.93	0.41
8	0.65	3.62	0.24	0.84	3.38	0.32
$L.S.D_{0.05}$	0.03	0.11	0.01	0.04	0.45	0.01
Proline (P), mg/L						
0	0.77	2.96	0.33	0.97	2.76	0.45
100	0.74	3.06	0.31	0.94	2.88	0.42
200	0.71	3.10	0.30	0.91	2.94	0.40
$L.S.D_{0.05}$	0.02	0.12	0.01	0.02	0.16	0.01
Interactions						
S x K	N.S	0.23	0.01	N.S	N.S	0.02
S x P	N.S	N.S	0.01	N.S	N.S	0.02
K x P	N.S	N.S	0.01	N.S	N.S	N.S
S x K x P	N.S	N.S	N.S	N.S	N.S	N.S

Table 6. Effect of irrigation water salinity, potassium nitrate and proline on Cl^-, NO_3^- contents, Cl/NO_3 ratio and proline contents of corn plants with or without leaching.

Treatment	with leaching				without leaching			
	Cl^-	NO_3^-	Cl/NO_3	Proline	Cl^-	NO_3^-	Cl/NO_3	Proline
	(mg g^{-1})							
salinity of irrigation water (S), dS/m								
0.54	3.77	1.40	2.98	0.87	4.82	3.08	2.13	1.60
3.36	13.77	1.37	10.81	1.41	15.63	2.01	8.70	1.98
5.88	16.50	0.92	19.91	1.85	19.22	1.76	11.86	2.29
7.95	19.58	0.66	39.81	1.88	22.69	1.20	19.62	2.60
$L.S.D_{0.05}$	0.51	0.01	0.16	0.05	2.87	0.04	0.18	0.04
Potassium nitrate (K), g/pot								
0	14.41	0.73	29.90	1.59	16.98	1.22	15.06	2.36
4	13.44	1.03	15.60	1.36	15.59	2.02	9.49	1.96
8	12.36	1.50	9.63	1.56	14.20	2.80	7.18	2.03
$L.S.D_{0.05}$	0.15	0.01	0. 08	0.02	1.56	0.04	0.10	0.03
Proline (P), mg/L								
0	13.74	1.03	20.82	0.95	16.04	1.90	11.41	1.45
100	13.40	1.10	18.00	1.64	15.61	2.04	10.54	2.40
200	13.06	1.14	16.32	1.93	15.13	2.10	9.78	2.50
$L.S.D_{0.05}$	0.04	0.01	0. 04	0.01	0.71	0.03	0.09	0.03
Interactions								
S x K	N.S	0.02	0.16	0.04	N.S	0.07	0.19	0.07
S x P	0.07	N.S	0.09	0.03	N.S	0.06	0.17	0.06
K x P	N.S	0.02	0.08	0.02	N.S	0.05	0.15	0.05
S x K x P	N.S	N.S	0.15	0.05	N.S	0.10	0.30	0.10

Table (7). Effect of irrigation water salinity, potassium nitrate and proline with or without leaching, on the *EC (dS/m) of soil collected after harvesting of corn plants.

Treatment	With leaching	Without leaching
salinity of irrigation water (S), dS/m		
0.54	0.91	1.15
3.36	1.28	1.80
5.88	4.48	5.32
7.95	6.27	8.67
L.S.D $_{0.05}$	0.45	0.45
Potassium nitrate (K), g/pot		
0	2.14	2.54
4	3.31	4.20
8	4.59	5.96
L.S.D $_{0.05}$	0.28	0.30
Proline (P), mg/L		
0	3.30	4.27
100	3.23	4.23
200	3. 18	4.20
L.S.D $_{0.05}$	0.19	0.23
Interactions		
S x K	0.56	0.60
S x P	N.S	N.S
K x P	N.S	N.S
S x K x P	N.S	N.S

*EC of soil-water extract (1:1 w/v) was measured

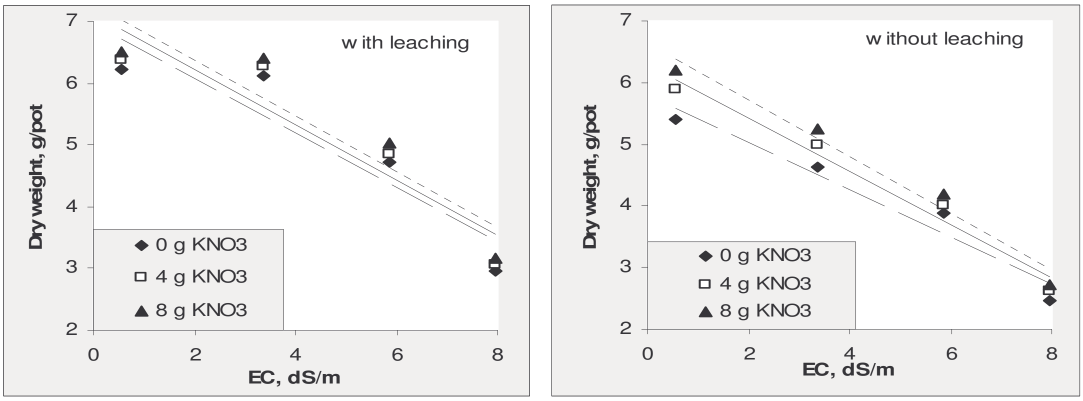


Fig 1. The relationship between the irrigation water salinity and the dry weight of corn shoot as affected by KNO_3 fertilization rate with or without leaching treatment

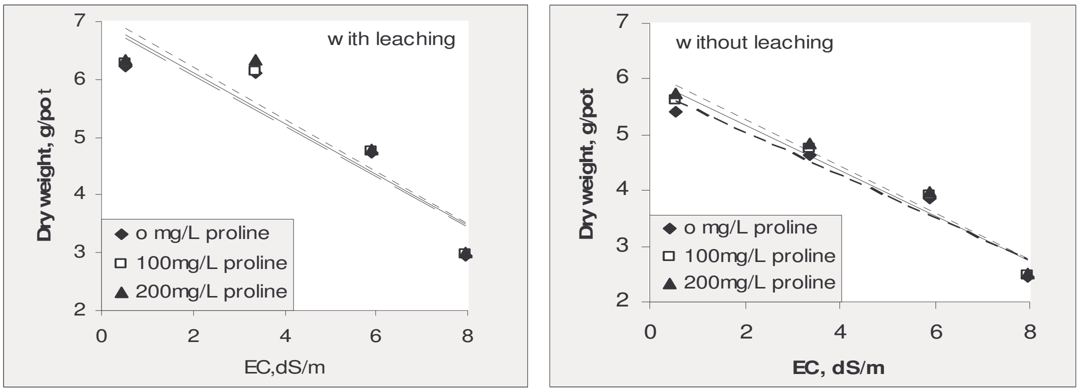


Fig 2. The relationship between the irrigation water salinity and the dry weight of corn shoot as affected by proline application rate rate with or without leaching treatment

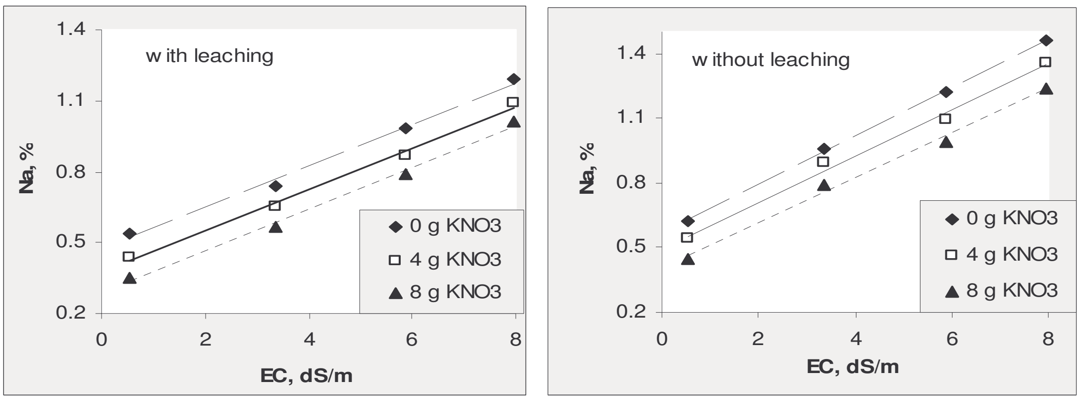


Fig 3. The relationship between the irrigation water salinity and the Na^+ contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

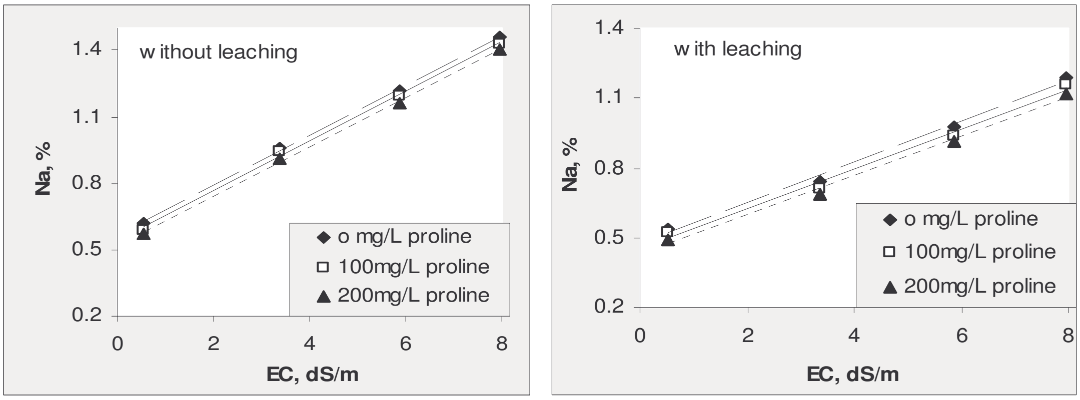


Fig 4. The relationship between the irrigation water salinity and the Na^{+} contents in corn shoots as affected by proline application rate with or without leaching treatment

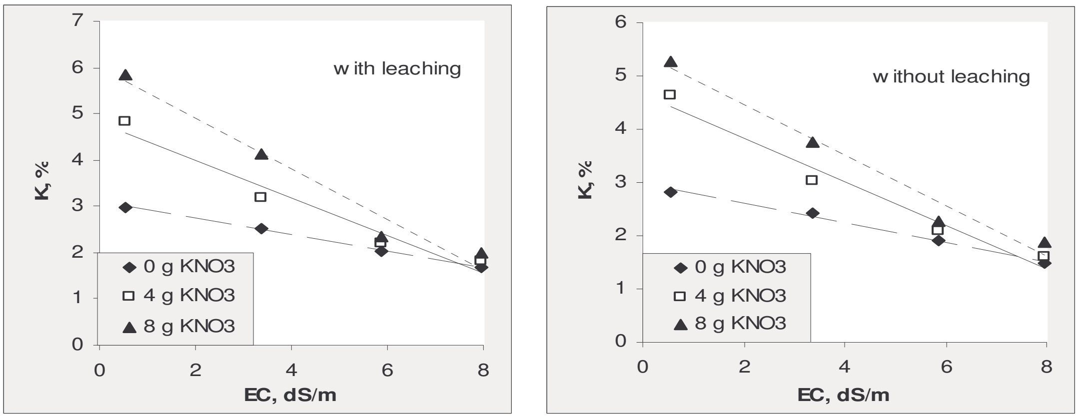


Fig 5. The relationship between the irrigation water salinity and the K^{+} contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

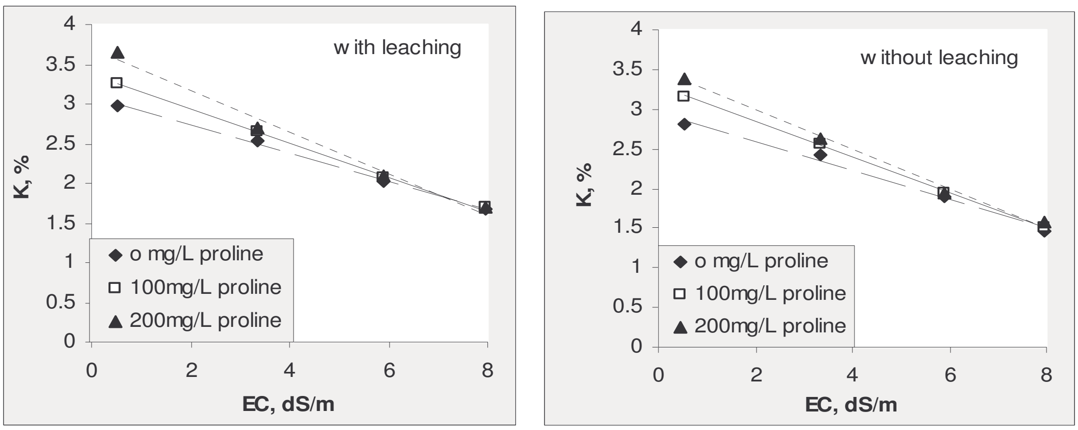
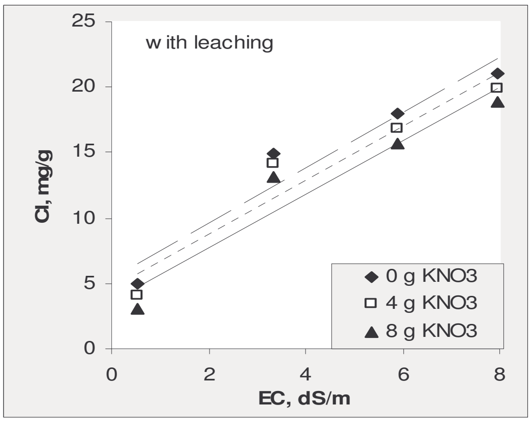


Fig 6. The relationship between the irrigation water salinity and the K^{+} contents in corn shoots as affected by proline application rate with or without leaching treatment



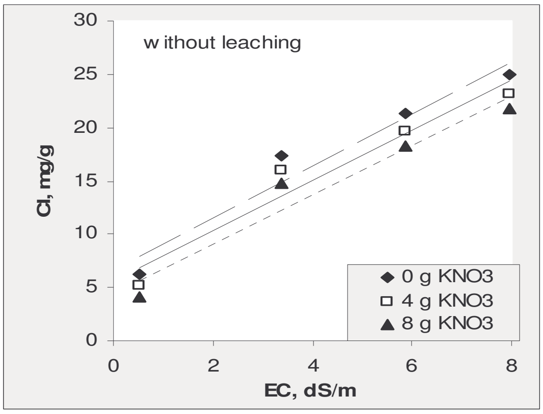
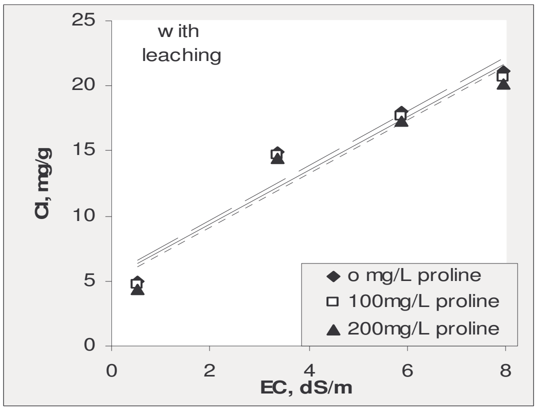


Fig 7. The relationship between the irrigation water salinity and the Cl^- contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment



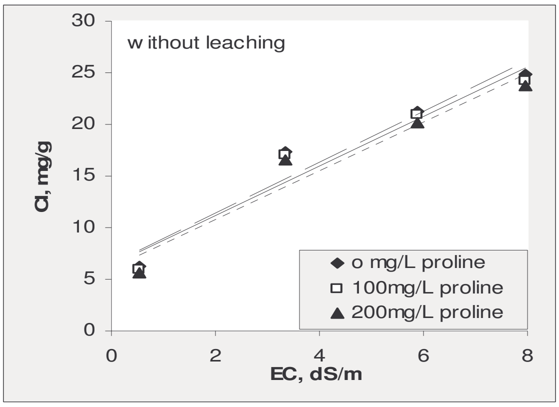
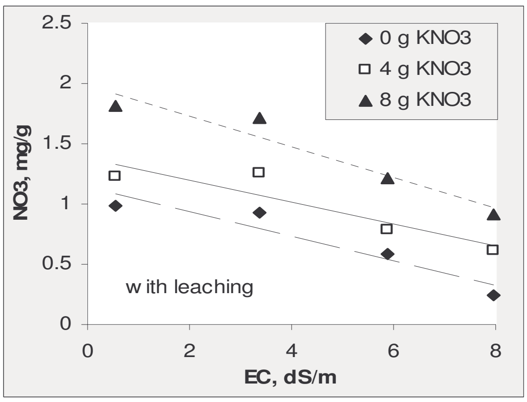


Fig 8. The relationship between the irrigation water salinity and the Cl^- contents in corn shoots as affected by proline application rate with or without leaching treatment



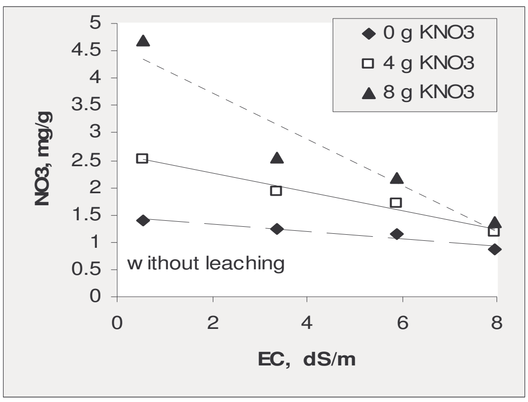


Fig 9. The relationship between the irrigation water salinity and the NO_3^- contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

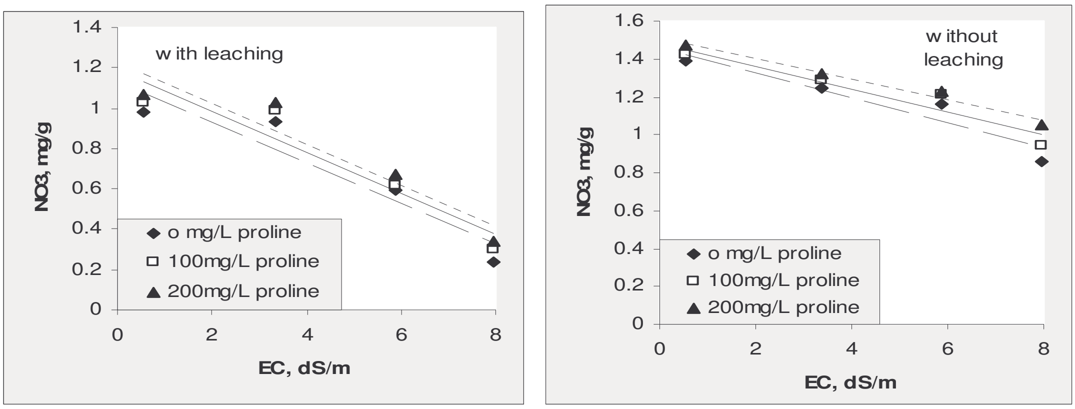


Fig 10. The relationship between the irrigation water salinity and the Cl^- contents in corn shoots as affected by proline application rate with or without leaching treatment

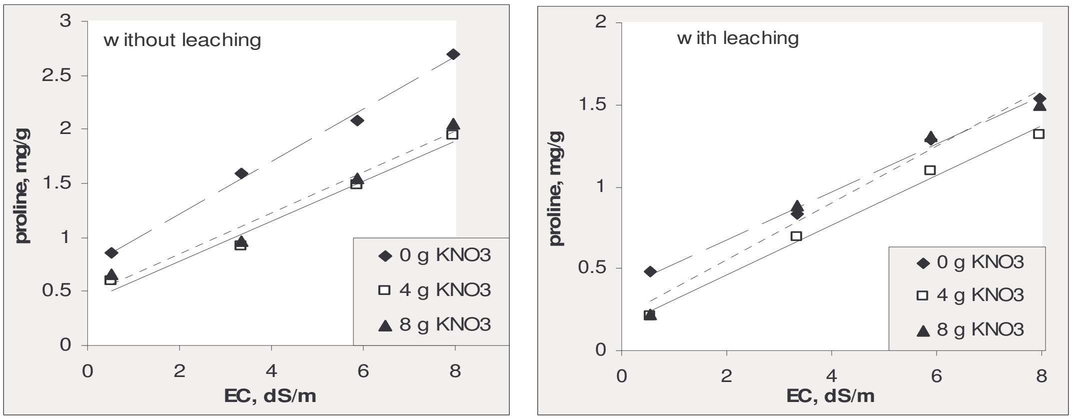


Fig 11. The relationship between the irrigation water salinity and the proline contents in corn leaves as affected by KNO_3 fertilization rate with or without leaching treatment

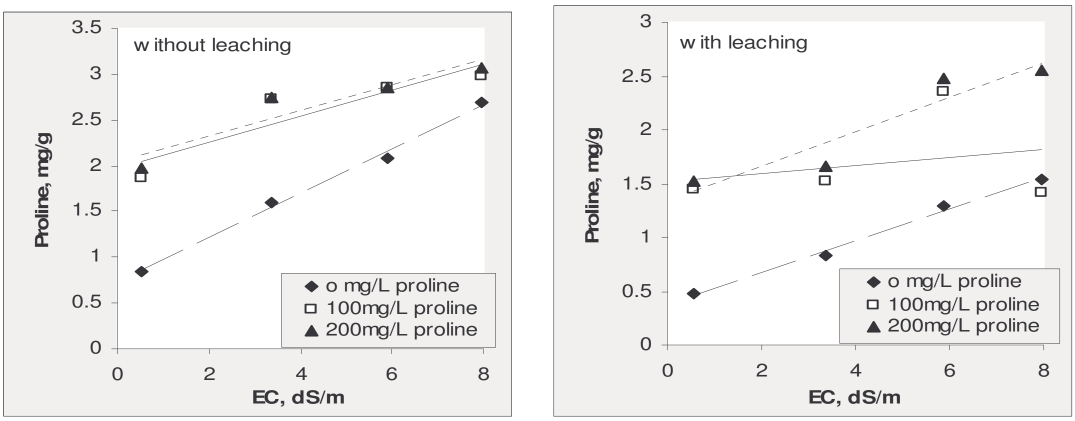


Fig 12. The relationship between the irrigation water salinity and the proline contents in corn leaves as affected by proline application rate with or without leaching