Interactive effect of salinity and two nitrogen fertilizers on growth and composition of sorghum

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ABSTRACT

The objective of this study was to investigate the interactive effects of salinity and different sources of applied N on growth, yield and nutrient composition of sorghum. The salinity treatments C_0, C_1, C_2, C_3 and C_4 corresponded to 0.6, 6, 8, 10 and 12 dS/m, respectively. Eight fertilization treatments combined urea and ammonium nitrate sources. The height, fresh weight, dry weight, leaf area, N, K, Ca, Mg, Na and Cl contents of treated plants were measured after harvesting. Results indicate that both emergence and growth were significantly decreased by increasing salinity. The plant response to N fertilizers appeared to be different at each salinity level. The maximum production of C_0 treatment was obtained for N-3, while at C_1 and C_2 treatments the maximum yield was obtained for N-2 and N-1 treatments, respectively. In the saline treatments, there was no significant difference between the two applied N-sources. The N, Ca, Mg, Na and Cl concentrations in plant tissues increased with increasing salinity; K concentration and the uptake of N, K, Ca and Mg were however decreased.

Keywords: nitrogen; salinity; sorghum

It is difficult to study plant response to fertilizers under saline conditions due to high concentration of salts and nutritional imbalances. Studies showed that application of fertilizers in saline soils might result in increased, decreased or unchanged plant salt tolerance. In other words, plant response to fertilizers depends on severity of salt stress in the root zone (Maas and Grattan 1999). Under low salinity stress, nutrient deficiency limits plant growth more than salinity and a positive interaction or an increased salt tolerance response occurs. While under moderate and high salinity, the limiting effect of salinity also affects plant growth (Hu et al. 1997, Grattan and Grieve 1999).

Most investigations on salinity-nitrogen issue focused either on nitrogen influence on plant (e.g. Özer et al. 2004, Svoboda and Haberle 2006) or on salinity as limiting plant growth factor (e.g. Burger and Čelková 2003, Orak and Ateş 2005, Supanjani and Lee 2006). Only few publications are available in the literature on interactive effects of salinity and nitrogen fertilization. Application of fertilizers to saline soils may exacerbate soil salinity conditions (Grattan and Grieve 1999). Most salinity and nitrogen interaction studies have been conducted on soils that were deficient in N. Therefore, application of N fertilizers improved growth and/or yield of corn, wheat (Soliman et al. 1994), cotton, millet and rice (Grattan and Grieve 1999). In most of these studies, the fact that applied N did not improve the growth under extreme saline conditions suggests that applied N decreased plant salt tolerance (Grattan and Grieve 1999). Halophytes grown in highly saline and N-deficient environments and glycophytes grown in mildly saline and N-deficient environments respond similarly to added N (Okusanya and Ungar 1984). Some studies also indicate that corn and cotton dry matter decreased by increasing salinity but increases by N application (Homaee et al. 2002).

In salinity and nitrogen interactive studies, the form in which N is supplied is important. Some studies indicate that increased nitrate in nutrient solution would decrease chloride uptake and its accumulation (Feigin et al. 1987, Martinez and Cerda 1989). Tshivhandekano and Lewis (1993) showed that NH_4^+-fed wheat and maize were more sensitive to salinity than NO_3^--fed plants when grown in solution culture.

Activity of nutrients in soil solution is affected by high concentrations of salt ions, usually Na and Cl, resulting in a nutritional disorder in plants (Grattan and Grieve 1999). Interactive effect of salinity and nutrients on the plant growth may be associated with the nutrient status in plant tissues (Hu and Schmidhalter 1997). Accumulation of Na and Cl in leaves through the transpiration flow, is a general and long-term process occurring in salt-stress plants (Munns and Termaat 1986).

Nutrient uptake and accumulation by plants is often reduced under saline conditions as a result of competitive process between the nutrient and a major salt species. However, this depends on the type of nutrients and composition of soil solution (Grattan and Grieve 1999, Maas and Grattan 1999, Homaee et al. 2002). Although plants selectively absorb potassium over sodium, Na^+-induced K^+ deficiency can develop on crops under salinity stress by Na^+ salt (Maas and Grattan 1999).

Most studies related to plant nutrition and salinity interactions have been conducted in sand or solution cultures. A major difficulty in understanding plant nutrition status as affected by soil salinity is reconciling results obtained in experiments conducted in the field and in solution cultures (Grattan and Grieve 1999). Thus it is likely that plant responses and interactions observed in artificial media may not necessarily, at least with the same magnitude, be as they would under natural conditions.

While application of fertilizers could improve plant nutritional status, it may also increase the salinity of soil solution. This study aimed at finding out at what extent nitrogen fertilizer must be applied in saline soils; its main objective was to investigate the interactive effects of salinity and nitrogen fertilizer on growth and composition of nutrients in sorghum. Further, the relationship between mineral nutrients concentration in plant tissues and growth indices under saline conditions was studied.

MATERIAL AND METHODS

Sorghum (*Sorghum bicolor* L. Moench) was selected for this study, because it is categorized as a moderately salt tolerant plant. Its salinity threshold value is reported to be 6.8 dS/m with the slope of 16 percent per each dS/m (Maas and Grattan 1999).

A randomized complete factorial blocks experiment with three replicates was conducted under large lysimeters with 120 cm height and 50 cm diameter. The needed experimental soils were taken from 0–25 cm surface layer of a natural saline soil. The collected soil was then air-dried and passed through an 8 mm sieve for pot experiment and a 2 mm sieve for chemical analysis. Some physical and chemical characteristics of the experimental soil are given in Table 1. As can be seen in Table 1, unlike previous studies, the soil was originally saline and was no not necessary to artificially create salinity.

The applied irrigation waters consisted of C_0, C_1, C_2, C_3 and C_4 corresponding to 0.6, 6, 8, 10 and 12 dS/m, respectively. The applied saline water treatments were prepared by diluting the natural saline water (80 dS/m) with fresh water (no artificial saline water was applied). Table 2 illustrates the chemical properties of the applied water for the experimental treatments. The applied fertilizers consisted of eight nitrogen levels. These were no fertilizers (F_0), triple super phosphate as a base fertilizer with no N-fertilizers (N_0 or control treatment), urea treatments and ammonium nitrate treatments. Each urea and NH_4NO_3 treatments consisted of three levels including 114, 137 and 160 kg elemental nitrogen per ha. These amounts correspond to 87, 100 and 117% of N requirement in non-saline soils, respectively (U_1, U_2, U_3, A_1, A_2, A_3).

Twenty kg soil was placed in PVC pots. Five holes with 2 cm diameter were made at the bottoms of each lysimeter to facilitate the calculated leaching and to maintain soil salinity at the target amounts.

Table 1. Some physical and chemical properties of the experimental soil

Sand (%)	Silt (%)	Clay (%)	Texture	OC (%)	SP (%)	pH	EC_e (dS/m)	TNV (%)	K (mg/kg)	P (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
53	33	14	sandy loam	0.79	27	7.4	5.2	13.76	468	10.4	0.74	4.5	10	0.86

OC – organic carbon; SP – soil water saturation percentage; EC_e – electrical conductivity of soil extract. The K concentration was measured by flame photometer, P by Olsen method, using spectrophotometer, Zn, Fe, Mn and Cu by DTPA extract using atomic absorption apparatus

Table 2. Chemical properties of the applied water treatments

Treatment	EC_e (dS/m)	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
			(mg/l)						
C_0	0.6	7.96	19.5	0.8	87.2	12	25.6	17	24
C_1	6	7.92	1007	9.4	489.2	89.3	1747	17	768
C_2	8	7.84	1343	12.5	652.8	119	2329	17	1114
C_3	10	7.81	1679	15.2	816	149	2913	17	1459
C_4	12	7.72	2024	17.5	964	179	3493	17	1804

EC_e – electrical conductivity

The amount of 250 kg triple super phosphate per ha as a base fertilizer was calculated for each pot (except F_0) and was applied to the experimental soils. The calculated nitrogen fertilizers were applied in two portions before sowing and when the plant height reached to about 35–40 cm in C_0.

A number of 10 disinfected sorghum seeds were sown at 3 cm depth in each pot. The applied irrigation water was by 50 percent higher than the consumptive use of plants to achieve the target leaching fraction. By applying this amount of leaching, the salinity of soil saturation extract approached the salinity of applied irrigation waters. The soil salinity was further monitored by taking some soil samples from the pots that were prepared as backups of the experiment.

The emergence rate of each pot was obtained by daily calculating number of seedlings. Those experimental plants that received saline water with ECs of 10 and 12 dS/m were eliminated from the experiment after 7 and 9 weeks, respectively, due to chloride toxicity. The others were harvested at 77 days after seeding by cutting them at 2 cm above the soil surface. Immediately after harvesting, the fresh weights were recorded, using a digital balance. The plant heights and their leaf area (by leaf area meter) were also measured. The harvested plants were then dried at 65°C for 24 h, weighed and grounded to pass a 1 mm sieve. The grounded plants were digested by wet oxidation method, using sulfuric acid, salicylic acid, selenium and hydrogen peroxide mixture for subsequent mineral analysis. The plant height, fresh weight, dry weight and the leaf area were measured as growth indices. The nitrogen, potassium, calcium, magnesium, sodium and chloride contents of harvested plants were also measured. The nitrogen concentration was measured, using the Kjeldal method, sodium and potassium by flame photometer, and calcium and magnesium by atomic absorption apparatus. The nitrogen, potassium, calcium and magnesium uptake were also calculated. The experimental data were analyzed using ANOVA and the comparison of means was analyzed based on the Duncan's multiple range tests.

RESULTS AND DISCUSSION

Emergence

The statistical analysis of the obtained data indicated that the effects of water salinity, fertilizer and their interactive effects on plant emergence are significant ($\alpha = 1\%$). Water salinity caused to decrease the plant emergence. The highest rate of emergence was obtained for C_0 treatment (Table 3). In C_0, although the rate of plant emergence in different fertilization treatments had no significant difference, the highest rate of emergence belonged to F_0 and N_0 fertilization treatments. In other words, the emergence rate in the treatments with no N fertilizers was higher than other treatments and N fertilization before sowing decreased the sorghum emergence rate (Table 3). In C_2 treatment, the highest emergence rate was obtained for no fertilizers treatment (F_0). This indicates that N application decreased the emergence rate (Table 3). In C_3 and C_4 treatments the emergence rate in different fertilization treatments had no significant difference (Table 3). Thus the limiting effect of water salinity on plant emergence was definitely more significant than the fertilization effect. This resembles the finding of Wang and Shannon (1999) who reported that salt tolerance of soybean varieties differed and emergence rate significantly decreased when salinity of saturation extract reached to more than 3 dS/m. Thus, salinity delays the normal emergence of radicle and plumule through decreasing osmotic potential.

Table 3. The effect of salinity on percentage of sorghum emergence

Salinity	Fertilizer levels and sources							
	F_0	N_0	U_1	A_1	U_2	A_2	U_3	A_3
C_0	90^a	90^a	86.7^a	86.7^a	90^a	90^a	93.3^a	86.7^a
C_1	63.3^a	56.7^a	36.7^b	33.3^b	30^b	40b	36.7^b	40^b
C_2	46.7^a	30^b	26.7^b	36.7^b	23.3^b	30^b	26.7^b	26.7^b
C_3	16.7^a	13.3^a	16.7^a	13.3^a	10^a	13.3^a	20^a	16.7^a
C_4	13.3^a	13.3^a	13.3^a	10.0^a	13.3^a	10.0^a	13.3^a	10.0^a

Identical letters in each line show non-significant difference at 1% level as determined by the Duncan's multiple range tests. F_0 – no fertilizer treatment; N_0 – control fertilizer treatment (base fertilizers without N application); A_1, A_2, A_3, U_1, U_2, U_3 are the first to third levels of ammonium nitrate and urea fertilizers, respectively

Prolongation of this critical emergence period damages seedlings as result of pathogenic and environmental factors and thus decreased success of plant establishment.

The plant height, fresh weight, dry weight and the leaf area were measured as the growth indices. The effects of water salinity, nitrogen fertilizer and their interactive effects on these indices were significant (α = 1%).

Fresh and dry weights

The increase of water salinity caused a decrease of plant fresh and dry weights in such an extent that the average fresh and dry weights, compared to C_0 treatment, decreased to 13.7 and 26.5 percent in C_1 and to 24.0 and 50.6 in C_2, respectively (Figure 1a). Comparison of the averages based on the Duncan's multiple range test shows that in C_0 treatment (EC = 0.6 dS/m), both fresh and dry weights increased due to nitrogen application. As given in Figure 1b, the highest average was obtained for N-3 (the third level of nitrogen fertilization). In C_1 treatment (EC = 6 dS/m), by increasing N fertilization, both dry and fresh weights of sorghum increased compared to N_0 level. However, the highest average was obtained for N-2 (the second level of fertilization) (Figure 1c). As depicted in Figure 1d, in C_2 salinity treatment, the highest average dry and fresh weights were obtained for N-1 fertilization level. Thus, by increasing water salinity, the lower levels of nitrogen fertilization had a higher effect on increase of dry and fresh weights. In other words, in moderately saline treatments of C_1 (EC = 6 dS/m) and C_2 (EC = 8 dS/m), nitrogen application increased the fresh and dry weights, while more fertilization caused both of them to decrease. The obtained results also indicate that in high salinities, application of fertilizers in higher than ordinary rate may cause more salinity and osmotic pressure and may decrease water and nutrients uptake and decrease the growth. In other words, under low salinity, nutrients deficiency can be the main limitation for plant growth. However, under higher salinities, the salinity limits growth more than nutrient deficiency.

Leaf area

The leaf area decreased by increasing water salinity. The average leaf area in C_1 and C_2 treatments decreased by 24% and 35.4%, respectively, compared to C_0 (Figure 2a). This can be attributed to a decrease of photosynthesis area as the main damage of salinity stress that decrease dry matter production rate. The comparison of statistical means indicated that in C_0 treatment, the leaf area increased with increasing nitrogen fertilizer (Figure 2b). In C_1 treatment, the leaf area increased after nitrogen application. However, the highest leaf area was obtained for N-2 (Figure 2c). In C_2 treatment, the highest leaf area was obtained for N-1 (Figure 2d). It suggests that with increasing salinity the lower level of applied nitrogen has a higher influence on the increase of leaf area.

The plant height

The plant height decreased with increasing salinity. The average plant height in C_1 and C_2 treatments compared to C_0 decreased by 10.9 and 16.7%, respectively (Figure 3a). In C_0 treatment, height differences between fertilization treatments were

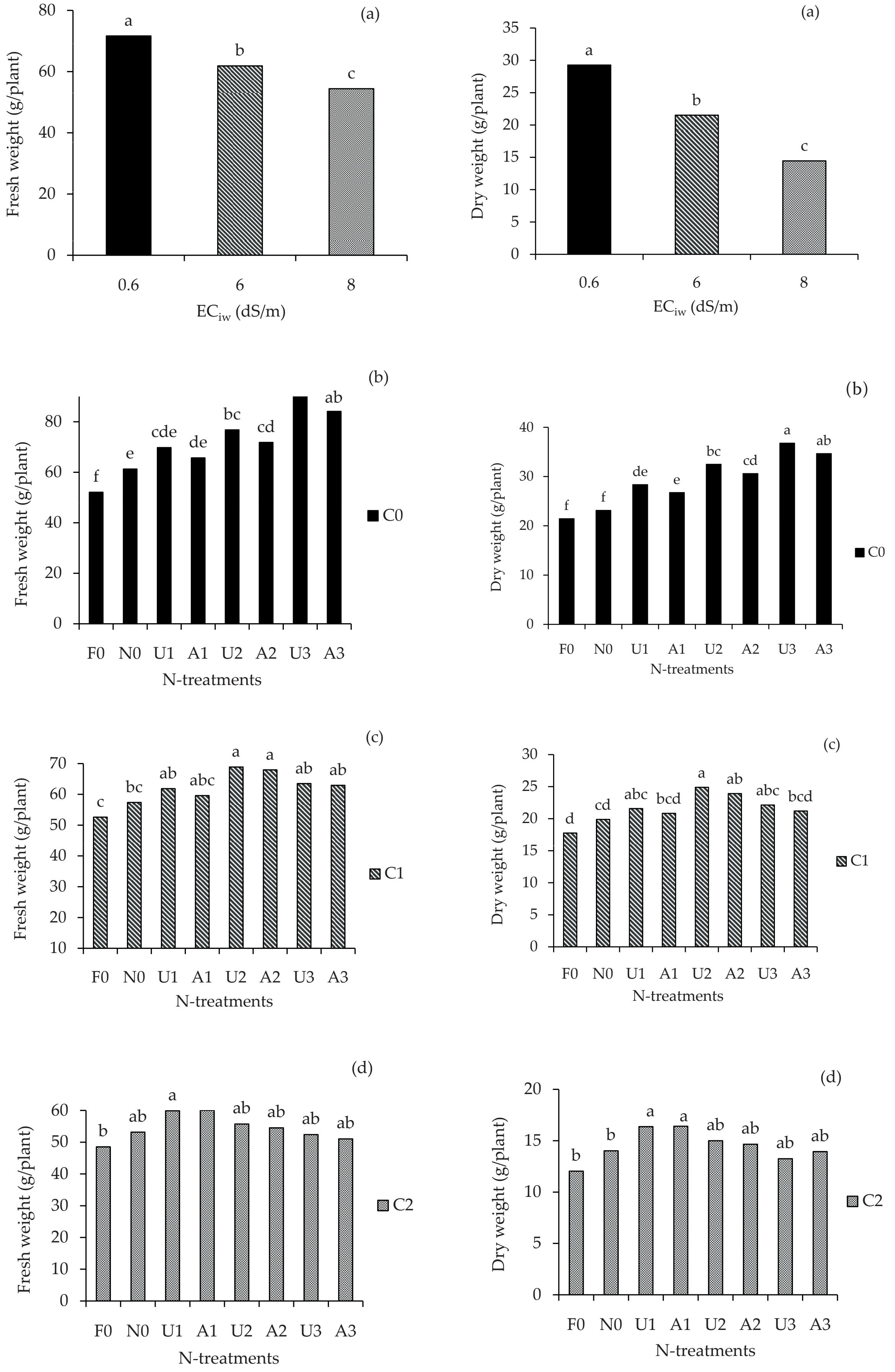

Figure 1. The effect of salinity and nitrogen treatments levels on fresh and dry weights of sorghum

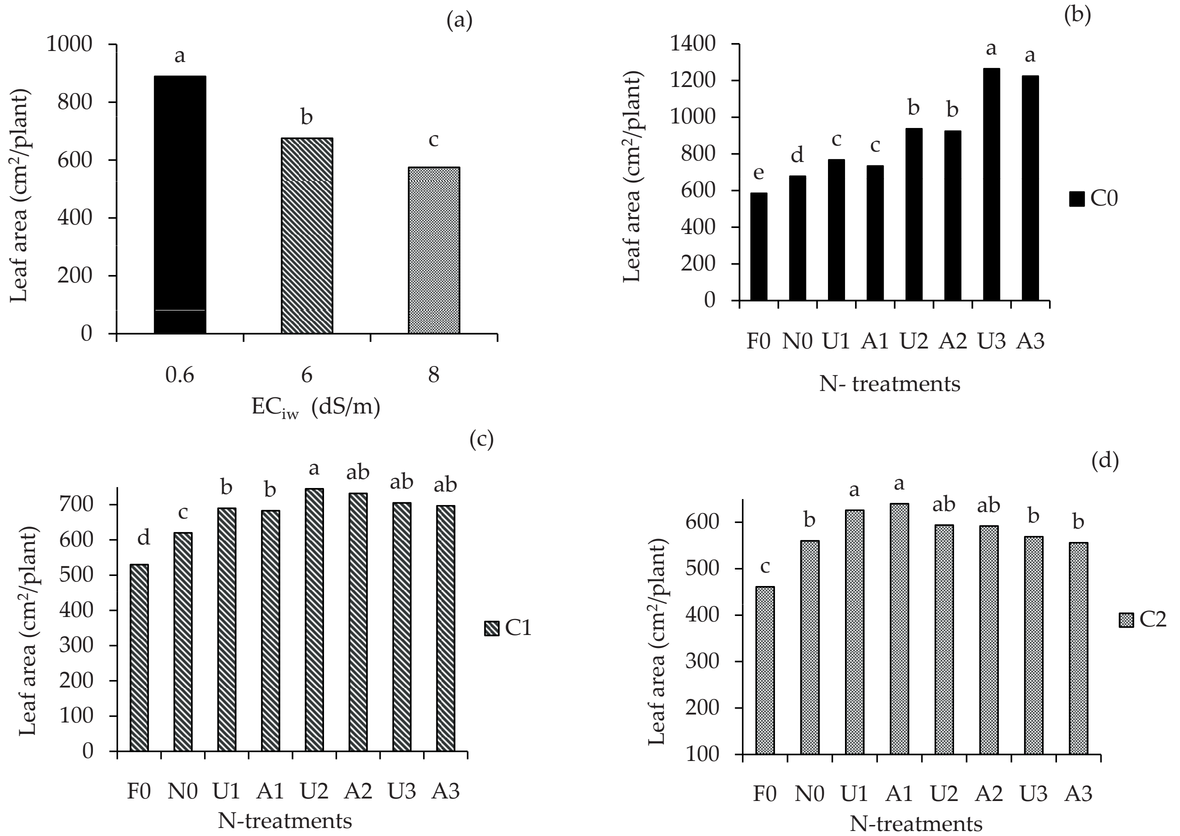

Figure 2. The effect of salinities (a) and nitrogen treatments levels on leaf area [(b) C_0, (c) C_1, (d) C_2]

not significant which might be related to nitrogen effect on tiller emergence (Figure 3b). In C_1 and C_2 treatments, the highest means were obtained for N-2 and N-1, respectively (Figure 3c and d).

Plant composition

The performed statistical analysis indicates that the effect of salinity on mineral nutrients composition in the experimental plant tissues is significant (α = 1%). The results presented in Table 4 indicate that the nitrogen concentration in tissues increased with increasing salinity.

As given in Table 4, the Ca and Mg concentration increased with increasing salinity. The average Ca concentration in C_1 and C_2 treatments compared to C_0 increased by 16.7 and 33.3 percent, respectively. For Mg this increase was 25 and 37.5 percent, respectively. This increase result from high concentrations of calcium and magnesium ions in saline water. On the other hand, salinity increase caused Ca and Mg uptake to decrease (Table 4), to such an extent that the average Ca uptake in C_1 and C_2 treatments compared to C_0 decreased by 11.1 and 33.3 percent, respectively. For the average Mg uptake this reduction was 20 and 40 percent for C_1 and C_2 treatments, respectively.

Through Ca and Na antagonistic effect on K uptake salinity caused to decrease K concentration in the tissues (Table 4). The average K concentration in C_1 and C_2 treatments compares to C_0 decreased by 11.5 and 15.1 percent, respectively. On the other hand, salinity through decreasing dry weight and K concentration caused to decrease the K uptake (Table 4). Some other researchers also reported that high Na concentration in growth media may diminish K concentration in some plant species (Greenway and Munns 1980, Rathert 1983). The decrease could be caused by the antagonism of Na and K at uptake sites of roots, to the effect of sodium on K transport into xylems (Lynch and Lauchli 1984) or to the inhibition uptake processes (Gronwald et al. 1990).

The data presented in Table 4 clearly indicate that Cl and Na concentration increased with increasing salinity. The average Cl concentrations in C_1 and C_2 treatments were 2 and 2.4 times higher than C_0 treatment. The average Na concentration in C_1 and C_2 treatments was 3.7 and 4.1 higher than C_0 treatment. This resembles the findings

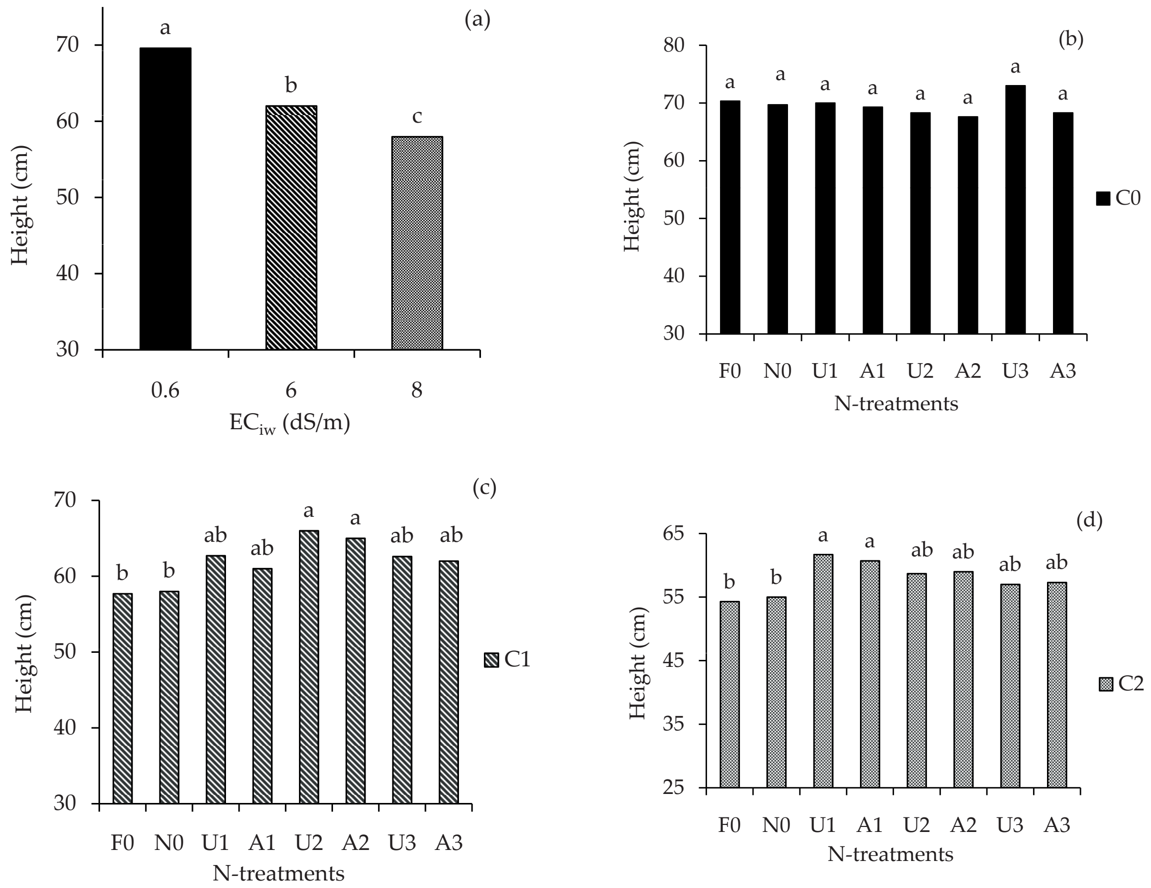

Figure 3. The effect of salinities (a) and nitrogen treatments levels on plant height [(b) C_0, (c) C_1, (d) C_2]

of Hu and Schmidhalter (1997) who reported that salinity increases Cl and Na concentrations and reduces K concentration in wheat.

The effect of nitrogen fertilizers on mineral nutrient concentrations and their uptake in plant tissues as well as the interactive effect of salinity and nitrogen fertilizers on nutrient uptake and concentrations of N, P and Cl were significant (α = 1%).

Based on the data presented in Tables 5 and 6, under all salinity levels the nitrogen application increased N concentration and its uptake. In C_0 treatment, K concentration was decreased by N application compared to N_0 (Table 6), but it was not significant. This decrease might be related to the effect of applied N on enhancement of plant dry weight (dilution effect). As can be seen in Table 5, in C_1 and C_2 treatments the K concentration was increased by N application. Also, N fertilization in all treatments has increased the K uptake (Table 6).

In C_0 treatment, both concentration and uptake of Ca and Mg were increased by N application as well as dry weight improvement (Tables 5 and 6). In C_1 and C_2 treatments, both concentration and uptake of Ca and Mg were increased by N application but this increase (except for Mg uptake at C_1 salinity level) was not significant (Table 5). The increase of Ca and Mg concentrations was probably caused by an increase of root exchange capacity resulting from N application and more uptakes of bivalent cations.

The statistical analysis indicated that in C_0 treatment, Na and Cl concentrations showed

Table 4. The effect of salinity levels on nutrient concentrations and uptakes

Salinity	N (%)	N-uptake (g)	K (%)	K-uptake (g)	Ca (%)	Ca-uptake (g)	Mg (%)	Mg-uptake (g)	Cl (%)	Na (%)
C_0	2.15^c	640^a	2.18^a	630^a	0.30^c	90^a	0.16^c	50^a	0.57^c	0.21^c
C_1	2.29^b	500^b	1.93^b	420^b	0.35^b	80^b	0.20^b	40^b	1.14^b	0.77^b
C_2	2.46^a	350^c	1.85^c	260^c	0.40^a	60^c	0.22^a	30^c	1.38^a	0.86^a

Table 5. The effect of salinity and nitrogen treatments levels on nutrient concentration (% dw)

Elements	Salinity	Fertilizer levels and sources							
		F_0	N_0	U_1	A_1	U_2	A_2	U_3	A_3
N	C_0	1.69^{e}	1.71^{e}	2.1^{d}	2.19^{cd}	2.62^{bcd}	2.32^{abc}	2.43^{ab}	2.48^{a}
	C_1	1.98^{d}	2.06^{d}	2.26^{c}	2.28^{bc}	2.36^{abc}	2.39^{abc}	2.48^{ab}	2.5^{a}
	C_2	2.09^{d}	2.12^{d}	2.48^{bc}	2.47^{c}	2.51^{bc}	2.56^{abc}	2.69^{ab}	2.75^{a}
K	C_0	2.31^{a}	2.24^{ab}	2.2^{ab}	2.18^{ab}	2.15^{ab}	2.14^{ab}	2.10^{b}	2.11^{b}
	C_1	1.68^{c}	1.71^{c}	1.90^{b}	1.95^{ab}	2.01^{ab}	2.06^{ab}	2.07^{ab}	2.09^{a}
	C_2	1.67^{b}	1.71^{b}	1.88^{a}	1.91^{a}	1.93^{a}	1.88^{a}	1.91a	1.89^{a}
Ca	C_0	0.23^{c}	0.25^{c}	0.26^{c}	0.28^{ab}	0.35^{ab}	0.34^{ab}	0.37^{a}	0.36^{a}
	C_1	0.30^{a}	0.32^{a}	0.45^{a}	0.35^{a}	0.36^{a}	0.37^{a}	0.37^{a}	0.36^{a}
	C_2	0.36^{a}	0.37^{a}	0.40^{a}	0.41^{a}	0.42^{a}	0.41^{a}	0.43^{a}	0.42^{a}
Mg	C_0	0.13^{b}	0.13^{b}	0.16^{ab}	0.17^{a}	0.18^{a}	0.18^{a}	0.18^{a}	0.18^{a}
	C_1	0.17^{b}	0.18^{ab}	0.20^{ab}	0.19^{ab}	0.19^{ab}	0.20^{ab}	0.19^{ab}	0.21^{ab}
	C_2	0.20^{a}	0.20^{a}	0.22^{a}	0.22^{a}	0.21^{a}	0.22^{a}	0.23^{a}	0.22^{a}
Cl	C_0	0.51^{a}	0.53^{a}	0.59^{a}	0.50^{a}	0.62^{a}	0.55^{a}	0.64^{a}	0.58^{a}
	C_1	1.29^{ab}	1.38^{a}	1.21^{abc}	1.16^{bcd}	1.09^{cde}	1.06^{cde}	0.99^{de}	0.93^{e}
	C_2	1.45^{ab}	1.52^{a}	1.35^{bc}	1.38^{bc}	1.36^{bc}	1.33^{bc}	1.36^{bc}	1.29^{c}
Na	C_0	0.17^{a}	0.30^{a}	0.18^{a}	0.17^{a}	0.21^{a}	0.18^{a}	0.26^{a}	0.22^{a}
	C_1	0.90^{ab}	0.91^{a}	0.79^{abc}	0.76^{abc}	0.73^{abc}	0.71^{bc}	0.69^{c}	0.66^{c}
	C_2	0.97^{ab}	1.06^{a}	0.83^{bc}	0.84^{bc}	0.83^{bc}	0.78^{c}	0.80^{bc}	0.76^{c}

Identical letters in each line show non-significant difference at 1% level as determined by the Duncan's multiple range tests. F_0 – no fertilizer treatment; N_0 – control fertilizer treatment (just base fertilizer without N application); A_1, A_2, A_3, U_1, U_2, U_3 are the first to third levels of ammonium nitrate and urea fertilizers, respectively

no significant differences between the fertilization treatments (Table 5). In C_1 and C_2 treatments, Na and Cl concentrations decreased by nitrogen fertilization compared to N_0 (Table 5). This decrease might be related to antagonistic effect between chloride, nitrate, sodium and ammonium on uptake. Therefore, in saline conditions the effect of specific ion toxicity, essential nutrients deficiency and nutritional disorder are the main effective factors to reduce growth.

Fertilizer type

In the non-saline treatment (C_0), the dry and fresh weights of urea treatments were significantly higher than ammonium nitrate, but the difference was not significant (Figure 1a and b). This can be related to the fact that some portions of nitrate leached out from the root zone because of high irrigation water application. On the other hand, most of the applied N in the soil was not in available form because of its low chemical mobility. The mineralization process should thus take place to transform the given N into the available forms. Consequently, it may be concluded that soil salinity reversely influences the mineralization process. It was anticipated that in saline conditions, ammonium nitrate treatments provide better plant growth compared to urea treatments. Due to nitrate leaching from the experimental soils, this process was however minimized. In both C_1 and C_2 treatments, possibly due to nitrate leaching as well as decrease of urea mineralization process, there was no difference between various N fertilizers types (Figure 1c and d).

The overall results obtained in this study indicate that salinity through increasing osmotic pressure, particularly at the soil surface, severely reduces the emergence rate and destroys the emerged seedlings at early growth stage. The irrigation water quality should be thus taken into account

Table 6. The effect of salinity and nitrogen treatments levels on nutrient uptake (mg/plant)

Elements	Salinity	Fertilizer levels and sources							
		F_0	N_0	U_1	A_1	U_2	A_2	U_3	A_3
N	C_0	360^{d}	397^{d}	597^{c}	583^{c}	730^{b}	710^{b}	893^{a}	857^{a}
	C_1	350^{d}	413^{cd}	487^{bc}	477^{bc}	590^{a}	573^{a}	547^{ab}	530^{ab}
	C_2	253^{c}	297^{bc}	407^{a}	407^{a}	377^{a}	370^{ab}	337^{ab}	383^{a}
K	C_0	493^{g}	520^{fg}	623^{de}	580^{ef}	700^{bc}	653^{cd}	777^{a}	730^{ab}
	C_1	297^{d}	343^{cd}	407^{bc}	407^{bc}	500^{a}	493^{a}	457^{ab}	443^{ab}
	C_2	203^{c}	237^{bc}	307^{a}	310^{a}	287^{ab}	273^{ab}	237^{ab}	263^{ab}
Ca	C_0	50^{d}	58^{cd}	73^{c}	74^{c}	113^{b}	106^{b}	135^{a}	125^{ab}
	C_1	54^{b}	64^{ab}	76^{ab}	73^{ab}	90^{a}	89^{a}	84^{ab}	78^{ab}
	C_2	43^{a}	52^{a}	66^{a}	67^{a}	64^{a}	60^{a}	57^{a}	59^{a}
Mg	C_0	28^{d}	30^{d}	44^{c}	45^{c}	57^{ab}	54^{bc}	65^{a}	61^{ab}
	C_1	31^{c}	36^{bc}	44^{ab}	40^{abc}	48^{a}	49^{a}	42^{ab}	44^{ab}
	C_2	24^{b}	29^{ab}	36^{a}	37^{a}	32^{ab}	32^{ab}	31^{ab}	31^{ab}

Identical letters in each line show non-significant difference at 1% level as determined by the Duncan's multiple range tests. F_0 – no fertilizer treatment; N_0 – control fertilizer treatment (just base fertilizer without N fertilizers); A_1, A_2, A_3, U_1, U_2, U_3 are the first to third levels of ammonium nitrate and urea fertilizers, respectively

at least before plant establishment in the soil. To achieve this, the salinity of soil surface should be controlled by using non- or low-saline irrigation water, as well as short irrigation intervals. In order to maintain salinity at a desire value in saline soils, the applied water is high and it is recommended to use split application of N fertilizers to minimize N leaching. It is also recommended to apply the first N fertilizer portion after emergence of seedlings. This practice will tend to minimize N leaching without influencing emergence rate resulting from high osmotic pressure. In this study, some interactive effects between soil salinities and various levels of N-fertilizers were observed. The sorghum response to nitrogen fertilizers was different in various salinity and fertilization levels. Nitrogen fertilization in saline water treatments increased sorghum salt tolerance by improving nutrients status. Results of this study indicate that soil salinity tend to reduce N, P, Ca and Mg uptake and increase Na and Cl concentrations in the plant tissues. Thus it decreases the dry weight of plant. In saline treatments, N fertilization however increased N, P and to some extent Ca and Mg uptakes and decreased Na and Cl concentrations. Consequently, the sorghum salt tolerance was increased.

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