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Impact of salinity and sodicity on biomass, total nitrogen, nitrate reductase activity, leaf area, and chlorophyll contents in maize (*Zea mays* L.)

M.Gufran Khan[1]*, G.Shimelis[1], H.Alemu[1], F.Kebenu[2]

[1]Department of Plant Science, College of Dryland Agriculture, Samara University, Afar, POB 132, (ETHIOPIA)

[2]Department of Nat.Res.Mgt., College of Dryland Agriculture, Samara University, Afar, POB 132, (ETHIOPIA)

E-mail: mgufran2001@ yahoo.com

ABSTRACT

Salinity and sodicity are major constraint in increasing crop production at global level. Millions of the hectares of the land are too saline to produce economic yield. In Ethiopia, 11 million ha of land is salt affected, about half of these soils are saline and remaining half are saline - sodic and sodic soil. As most of the arable land and quality water resources have already been exploited, the use of saline or urban/industrial waste water may be a viable alternative for further agro production. In view of such perspectives, an investigation was conducted to examine the effect of salinity (NaCl) and sodicity (Na_2CO_3) on biomass, total nitrogen, nitrate reductase activity, leaf area, and chlorophyll contents in Maize (*Zea mays* L.) plants. The appropriate amount of NaCl and Na_2CO_3 was dissolved in distilled water for appraisal of artificial salinity and sodicity levels (0, 4, 8, and 12 and $mScm^{-1}$) in soil medium. Plants were also supplied with potassium (0 and 5mM KNO_3) as remedial treatment. Maize plants were analyzed for germination, early growth, biomass, total nitrogen, Nitrate reductase activity, Leaf area, and chlorophyll contents as grown under different ECe levels of salinity and sodicity. The extent of salinity and sodicity effects was compared on the basis of different parameters. It was observed that plants showed substantial reduction in all parameters due to imposition of salinity and sodicity in root medium and it was more so due to sodicity. However, the use of additional potassium brought about an enhancement in these parameters. It is suggested that plants may be raised in saline soil and saline water however; the extent of success depends upon salinity and sodicity levels, remedial treatments and plant species. The outcome of the present work may contribute towards viable utilization of saline soil and water for enhancing agro production of suitable crops, a desired goal to achieve food security.

KEYWORDS

Salinity and sodicity;
Maize;
Electrical conductivity (ECe), germination.

INTRODUCTION

The problem of salinity and sodicity is worldwide. Millions of hectares of the land are too saline to produce economic yield. According to an estimate, more than 800 million hectares of land throughout the world are salt affected either by salinity (397 million ha) or the associated conditions of sodicity (434 million ha)[4]. In an another estimate, it has reached 19.5% of the irrigated land and 2.1 % of the dry land agriculture existing on the globe[3]. In Ethiopia also, 11 million ha of land are salt affected, about half of these soils are saline and remaining half are saline –sodic and sodic soil. Soil salinity and related problems generally occur in arid or semi arid climates where rainfall is insufficient to leach soluble salts from the soil or where surface or internal soil drainage is restricted. Salinity problems can also occur on irrigated land, particularly when irrigation water quality is marginal or worse. In humid regions, salt problems are less likely because rainfall is sufficient to leach soluble salts from the soil, but even in higher rainfall areas, salinity problems occur. In some areas with high water tables, problems may occur with surface evaporation leaving salts to accumulate. Saline and sodic (alkali) soils can significantly reduce the value and productivity of affected land.

Potassium is essential for protein synthesis, glycolytic enzymes and photosynthesis, in osmoticum mediating cell expansion and turgor driven movements and competitor of Na^+ and salt stress[8]. Accumulation of Na^+ and impairment of K^+ nutrition is a major characteristic of salt stressed plant. Application of K fertilizer reduces the adverse effect of salinity and sodicity through its role in stomatal regulation, osmoregualtion, energy status, charge balance, protein synthesis and homoeostasis[12,15].

In a developing country like Ethiopia, where million of hectares of land are becoming sick due to salinity and sodicity in areas like Awash, there is an imperative need to use such saline and alkaline soil for agriculture purposes by using various amendment measures. Moreover, the scarcity of irrigation water also tend to search alternative sources such as saline water for raising crops in order to fulfill the demand of increasing population of the country.

In view of such perspectives, the present work was aimed to determine the germination, growth and some other physiological parameters in maize crop grown in soil affected by salinity and sodicity. Maize (*Zea mays* L.) has been selected as test crop as it is grown largely in Ethiopia and consumed in various forms.

MATERIALS AND METHODS

Seeds of maize (*Zea mays* L.) were disinfected with 1% sodium hypochlorite solution for 15 minutes and washed in running tap water. The seeds were then sown in plastic pots containing 2 Kg of garden soil (pH: 7.8; ECe; 2.8 ms/cm). The desired ECe (i.e., 4. 8 and 12 mscm-1) levels of salinity and sodicity were achieved by dissolving appropriate amount of NaCl and Na_2CO_3 in distilled water[9], TABLE 1. After emergence of seedling, plants were irrigated with desired levels (0 4, 8 and 12 mScm-1) of salinity and sodicity. Plants were also irrigated alternately with simple tap water to avoid the excessive accumulation of salts in rhizosphere. Five Plants were raised in each pot and three replications were maintained for each treatment. Plants were taken from each treatment and analyzed.

Analysis and determinations

(a) Germination

Germination percentage of each crop from each treatment was calculated on the basis of radicle emergence from seeds.

(b) Biomass

Plant samples were taken from each treatment and divided into root and shoot parts. Plants were dried in a hot air oven at 60 °C for 48 hours and dry weights were estimated.

(c) Chlorophyll contents

The chlorophyll content in leaves of all crops of different treatments was estimated by extracting fresh leaves in acetone according to Strain and Svec (1966).

(d) Leaf area

Leaf area was calculated by measuring in length and width.

(e) Relative growth rate (RGR)

RGR of the whole plant was calculated by the formulae using dry weights on two occasions according to Hunt (1978).

(f) Total N content

Total N contents in plants parts i.e., root and shoot were determined by Micro Kjeldahl methods according to Snell and Snell (1966).

(g) In vitro nitrate reductase activity

Nitrate reductase activity was determined separately in leaf and root parts following a method as devised by Srivastava and Ormrod (1986).

(h) Statistical analysis

Statistical evaluation of data was carried out by factorial analysis of variance followed by Fisher's significant test (PLSD) at 5% P.

RESULTS AND DISCUSSION

Germination and biomass production

The mean values of percentage germination % and root and shoot length as affected by different concentrations of salinity and sodicity are presented in TABLE 2. It is obvious from data that at lower concentration (4 mScm-1) of salinity as well as sodicity, germination % was not affected (over control), whereas a considerable reduction was observed in early seedling growth i.e., root and shoot length even at 4 mSm-1 TABLE 2. However, this decrease over control was not significant at lower levels of salinity and sodicity. For example, at 12 mScm-1 concentration of salt stress, maize plants exhibited about 3.70 and 3.18 cm/plant root length under salinity and sodicity condition respectively as compared with 5.34 cm root length under control conditions (0 NaCl/Na_2CO_3). On the other hand, germination and early seedling growth were greatly decreased under higher concentrations (8 and 12 mScm-1) of salts i.e., NaCl and Na_2CO_3. Interestingly, this decreasing response of crop to higher concentrations was observed in root and shoot dry lengths also due to imposition of salinity and sodicity during the present study TABLE 2. However, the extent of reduction was variable TABLE 2. In contrary, the imposition of potassium in nutrient medium resulted into enhancement in germination as well as early seedling growth. For instance plants showed about 8.46 cm/plant shoot length in control plants followed by 3.60 and 3.12 cm shoot length in normal potassium fed plants as compared with 3.75 and 3.30 cm Shoot length in additional potassium fed plants under NaCl and Na_2CO_3 stressed conditions respectively. Overall performance of crop was variable to potassium in salt stressed and control (non-stressed) plants.

Biomass production and relative growth rate

During the present investigation, the inclusion of NaCl and Na_2CO_3 in nutrient medium resulted into a marked decrease in biomass as well as relative growth rate. However, it was more so due to Na_2CO_3. For instance, Plants exhibited about 29.4 % decrease over control in RGR by Na_2CO_3 as compared with

TABLE 1 : Amount of salt added per litre distilled water and resultant electrical Conductivity levels of soil (in mScm-1)

Salts	Amount of salts dissolved per Litre DW (in gms)	Ece Levels maintained at 25^{o}C (in mScm-1)
NaCl (control)	Nil	2.8
NaCl	2.25	4.2
NaCl	3.75	8.1
NaCl	6.50	12.2
Na_2CO_3 (Control)	Nil	2.8
Na_2CO_3	3.00	4.2
Na_2CO_3	7.50	8.1
Na_2CO_3	10.50	12.2

TABLE 2 : Effect of salinity and sodicity on germination % and early seedling growth in maize

Salt concentration (mScm-1)	KNO3 Conc (m M)	Germination %	Root Length (cm)	Shoot Length (cm)
0 NaCl	0	100a*	5.34a	8.46a
	5	100a	5.60b	8.60a
4	0	100a	5.12b	6.68b
	5	100a	5.20b	6.80b
8	0	90b	4.70c	4.40c
	5	90b	4.98c	4.75c
12	0	70d	3.70d	3.60d
	5	80e	3.90d	3.75d
0 Na_2CO_3	0	100a	5.34a	8.46a
	5	100a	5.60a	8.60a
4	0	100a	5.00b	5.80b
	5	100a	5.10b	5.95b
8	0	90b	4.15c	3.88c
	5	95b	4.35c	4.40d
12	0	60c	3.18d	3.12e
	5	70d	3.28d	3.30e

***Values followed by same letter are not significant at 5% P (Fisher PLSD test)**

23.8% decrease by NaCl at same concentration (8 mScm-1)) grown under similar environmental conditions. Nevertheless, this relatively higher decreasing effect of Na_2CO_3 was equally noticed in plants grown with or without additional potassium. For example, about 0.270 and 0.259 g/dw/d RGR was observed in plants under NaCl as compared with 0.265 and 0.240 g./dw/d RGR under Na_2CO_3 at 8 mSm-1 concentration in plants grown with and without additional potassium respectively. In addition, this promotive effect of potassium was also noticed in root and shoot dry weights when plants were subjected to salt stress conditions TABLE 3.

Total Nitrogen content and Nitrate reductase activity

It is obvious from the data in TABLE 4 that salinity and sodicity reduced the total nitrogen content in root and shoot and nitrate reductase activity in maize plants grown under various salt levels. On the other hand, like biomass, inclusion of potassium in nutrient medium brought about a substantial reduction in salinity and sodicity caused inhibition in these N contributory parameters. For example potassium reduced the NaCl caused reduction in total N content by 3.21 % and 4.78 % over control in root and shoot parts at 12 mScm-1 concentration respectively. Similarly, Potassium application also reduced the Na_2CO_3 caused reduction in N content in both plant parts TABLE 4.

Data presented in TABLE 4 clearly demonstrate the differential effects of salinity, sodicity and potassium application on *in vitro* nitrate reductase activity in maize plants parts. Higher NR activity was recorded when non stressed plants were fed with potassium in. However, the promotive effect of potassium was also substantial in NaCl or Na_2CO_3 stressed plants considering the extent of stimulation of NR activity in root and leaves tissues as index TABLE 4. For instance, plants exhibited about 15.7% and 19.2% reduction over control in NR activity in root under NaCl and Na_2CO_3 (8 mScm-1 level) respectively. However, it was decreased when

TABLE 3 : Effect of salinity and sodicity levels on biomass and relative growth rate (RGR) in maize plants

Salt concentrations (mScm-1)	Potassium Conc (mM)	Root DW (g/plant)	Shoot DW (g/plant)	Total DW (g/plant)	S:R ratio	Relative Gowth rate (g/gDW/day)
Control (0NaCl)	0	0.480a*	0.890a	1.370a	0.539a	0.340a
Control+ K	5	0.490a	0.910a	1.380a	0.538a	0.344a
4.0	0	0.440b	0.810b	1.258b	0.543b	0.350a
	5	0.445b	0.840b	1.270c	0.529b	0.359b
8.0	0	0.370c	0.750c	1.120d	0.493c	0.259c
	5	0.400c	0.780c	1.130e	0.512c	0.270c
12.0	0	0.290d	0.490d	0.780f	0.591d	0.210d
	5	0.305d	0.500d	0.795f	0.590d	0.220d
Control (0 Na_2C0_3)	0	0.480a	0.890a	1.370a	0.539a	0.340a
	5	0.490a	0.910a	1.380a	0.538a	0.344a
4.0	0	0.410b	0.800b	1.210b	0.512b	0.320a
	5	0.425b	0.810b	1.225b	0.524b	0.330b
8.0	0	0.340c	0.710c	1.050c	0.478c	0.240c
	5	0.350c	0.720c	1.090c	0.486c	0.265c
12.0	0	0.230d	0.425d	0.655d	0.541d	0.189d
	5	0.234d	0.429d	0.660d	0.545d	0.19d

*Values followed by same letter are not significant at 5% P (Fisher PLSD test)

TABLE 4: Effect of salinity and sodicity levels on Total N and Nitrate reductase activity in maize plant

Salt concentrations (mScm-1)	KNO3 Concentration (mM)	Total Nitrogen (mg/g DW) Root Shoot	Nitrate reductase Activity (µmol NO2/gFW/H)
0 NaCl	0	35.20a* 48.10a	2.85a 5.60a
	5	35.30a 48.80a	2.95a 5.70a
4	0	28.10b 37.00b	2.80a 5.50a
	5	29.40b 37.40b	3.00a 5.90a
8	0	22.15c 30.10c	2.40b 4.80b
	5	23.70c 30.50c	2.80b 5.70b
12	0	15.30d 25.60d	1.10c 2.50c
	5	16.50d 27.90d	1.20c 2.60c
0 Na_2CO_3	0	35.20a 48.10a	2.85a 5.60a
	5	35.30a 48.20a	2.95a 5.70a
4	0	26.40b 37.10b	2.70a 5.40a
	5	26.80b 37.80b	2.98a 5.70a
8	0	20.05c 26.80c	2.30b 4.15b
	5	21.30 26.90c	2.60b 4.45b
12	0	13.20d 23.40d	1.00c 2.05c
	5	14.80e 23.60d	1.10c 2.24c

***Values followed by same letter are not significant at 5% P (Fisher PLSD test**

potassium was supplied along with both salts.

Chlorophyll contents

It is obvious from data presented in TABLE 5 that the effect of different concentrations of salt stress viz., NaCl and Na_2CO_3 on various chlorophyll forms was differential in maize plants (*Zea mays* L.) during the investigation. It was observed that the greening of plants was not substantially decreased when plants were treated with low concentration of salts

TABLE 5 : Effect of salinity and sodicity on chlorophyll content and leaf area in maize plants

Salt concentrations (mScm-1)	KNO3 Conc (mM)	Chl a (mg/gFW)	Chl b (mg/gFW)	Total Chl (mg/gFW)	Leaf area (cm)2
0 NaCl	0	1.660a*	0.990a	2.700a	27.40a
	5	1.680a	0.997a	2.719a	27.90a
4	0	1.655a	0.880b	2.610b	27.20a
	5	1.715b	0.896b	2.630b	28.30b
8	0	1.430c	0.786c	2.350c	25.10c
	5	1.460c	0.800c	2.380c	25.90c
12	0	0.970d	0.650d	1.770d	18.00d
	5	0.990d	0.670d	1.775d	18.90d
0 Na_2CO_3	0	1.660a	0.990a	2.700a	27.40a
	5	1.680a	0.997a	2.719a	27.90a
4	0	1.450b	0.820b	2.550b	27.00a
	5	1.500b	0.840b	2.580b	27.80a
8	0	1.204c	0.710c	2.110c	18.90b
	5	1.280c	0.738c	2.150c	19.00b
12	0	0.887d	0.530d	1.540d	13.10c
	5	0.900d	0.550d	1.550d	13.28c

***Values followed by same letter are not significant at 5% P (Fisher PLSD test)**

(4mScm-[1]). Whereas it was also noticed that higher concentrations (8-12 mScm-1) were inhibitory to synthesis of all chlorophyll molecules particulary of Chl a TABLE 5. In contrary to the salt effect, inclusion of additional potassium in nutrient medium brought about a considerable enhancement in chlorophyll contents in stressed and non stressed plants.. For example, at 8 mScm-1 concentration, plants showed about 2.380 and 2.150 mg/gFw total chl content as compared with 2.350 and 2.110 mg/gFW total chlorophyll content in NaCl and Na_2CO_3 stressed plants respectively when supplied with additional potassium doses. This was a same case with non stressed plants (comtrol). For example, 2.700 mg/g FW total Chl was determined as compared with 2,719 mg/gm FW total Chl in control plants receiving no potassium.

Leaf area

Data presented in TABLE 5 show the average value of leaf area in plants while subjected to the different concentrations of NaCl and Na_2CO_3 salts. Like other parameters, leaf area was also affected differentially by the variable concentration of salts ie. higher levels of salinity and sodicity (8-12 mScm-1) were proved deleterious to leaf area whereas lower concentration induced leaf area in considerable manner TABLE 5. Data presented in TABLE 5 also show the promotive effect of potassium application on chlorophyll contents subjected to salt stress.

It is evident from the results that plants exhibited a decreasing trend in seed germination %, biomass, chlorophyll contents, leaf area, total N and nitrate reductase activity to increasing levels (0-12 mscm-1) of NaCl and Na_2CO_3. In contrary, a substantial increase was observed in these parameters when plants were supplied with additional potassium. Several reports favour the findings of present work as salinity and sodicity inhibited the germination, biomass production, chlorophyll content, total N contnents and nitrate reductase activity in other crop plants[9,13,14].

Inhibition of plant growth and productivity due to salinity and sodicity may be the result of osmotic disturbance. The osmotic adjustment i.e., reduction of cellular osmotic potential by net solute accumulation has been considered as an important mechanism to salt and drought tolerance in plant. This reduction can be result of inorganic ion (Na^+ Cl^- and K^+) and compatible organic solutes (eg,. Betaine, Glycine, Proline etc.,) accumulation[6]. The osmotic adjustment both in root and leaves contribute to the formation of water uptake and cell turgor allowing physiological processes like stomatal opening, photosynthesis and cell expansion[1,18]. In addition to their role in cell water relationship, organic solute accumulation may also help towards the maintenance of ionic homeostasis and of the C/N ratio, removal of free radicals and stabilization of organelles.

CONCLUSION

It is concluded that addition of potassium in nutrient medium may increase the crop growth resulting into good yield even under salinity and sodicity conditions, however, the extent of success depends upon the crop species, concentration of salts and age of plants. The present work shows the prospectus of use of saline and sodic soils and water for crop production by adapting better management and advanced agrarian methods leading towards food security and sustainable development, a desired goal to fulfill the ever increasing demand of population. However, further studies involving newer techniques are recommended to reach at more realistic conclusion.

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