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Effects of Natural Zeolite to Reduce Salt Stress in Kentucky bluegrass (*Poa pratensis*)

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Abstract

Salinity is one of the most important factors limiting growth and development in cultivated species. Kentucky bluegrass was grown in boxes filled with sand (100%), 95% sand: 5% zeolite, 90% sand: 10 % zeolite and 85% sand 15% zeolite (V/V). *Poa pratensis* plants were irrigated with 0.24, 3.4 and 6.4 $dS.m^{-1}$ salt water daily for 6 months in greenhouse condition to study the effect of different levels of zeolite on turf quality (TQ) and some physiological growth factors, salt deposition, sodium absorption ratio (SAR) and ion composition in leachate under different levels of salinity. Saline water reduced (PR), transpiration, (SC), (ME), (WUE), maximum assimilation rate (A_{max}), carboxylation efficiency (g'_{m}) and net assimilation rate (A_{360}) compared to control. Amendment of sand with zeolite increased TQ, PR, transpiration, SC, ME, WUE, (A_{max}), (g'_{m}) and (A_{360}) during both the 2nd & 3rd months at both salinity levels. Highest effect obtained in highest percent of zeolite. The beneficial effects of zeolite on turf quality and other parameters diminished 3 months after treatments. Amendment of sand with zeolite reduced leaching of Na and K but, increased leaching of Ca and Mg. Using zeolite in medium increased SAR value compared to control. Results indicate that amending with zeolite may buffer soil solution Na concentration in short-term. In the long-term, however, a substantial amount of Na may be retained concurrent with Ca & Mg exchange, thereby increasing sodicity & salinity problems.

Keywords: Maximum Assimilation Rate; Carboxylation Efficiency; Net Assimilation Rate; *Poa pratensis; Salinity; Zeolite.*

Introduction

Sand provides an ideal physical root zone media for *Poa pratensis* (Kentucky bluegrass) due to its particle size distribution which provide a firm surface for foot traffic while remaining highly permeable. However, sand has low water and nutrient retention properties. Organic and inorganic amendment are often add to sand base green medium to improve water and nutrient retention and to decrease bulk density (Hummel, 1993; Hung and Petrovic, 1994). One of these soil amendments is zeolites, which are ancient volcano ash-based materials. Zeolites are crystalline, hydrated aluminosilicates of alkali and earth metals that possess infinite, three-dimensional crystal structures. The most common natural zeolite is clinoptilolite. Applications of natural zeolites make use of one or more of the following properties: (*i*) cation exchange, (*ii*) adsorption and related molecularsieving, (*iii*) catalytic, (*iv*) dehydration and rehydration, and (*v*) biological reactivity. Extrinsic properties of the rock (e.g., siliceous composition, color, porosity, attrition resistance, and bulk density) are also important in many applications. Salinity is one of the most important factors limiting growth and development in cultivated species. Most of the salt stress in the nature is due to sodium salts, particularly sodium chloride (Meier and Olsen, 1971). Today the most common practice to alleviating salt stress is to increase leaching, that sometimes is expense and impractical option. Because of water conservation concerns, turfgrass are increasingly irrigated with non potable water, particularly effluent water or other marginal quality waters (Dean *et al.*, 1998; Hayers *et al.*, 1990a). In situation where salinity is a problem, using soil amendment like zeolite that have high CEC may retain salt, reduce their leaching and accentuate root zone salinity problem. So, understanding the possible influence of zeolite on salt leaching and growth of turf grass will be useful in selecting soil amendment and management approaches. The objectives of this investigation were the effect of different levels of zeolite on turf quality (TQ) and some physiological growth factors, salt deposition, sodium absorption ratio (SAR) and ion composition in leachate under different levels of salinity.

Materials and Methods

The experiment was conducted in the horticultural science department greenhouse between July 2006 and Mars 2007. Plants were maintained in a heated greenhouse under natural light (>800 μmol m^{-2} s^{-1}) at a day temperature of 23±2 C and night temperature of 13±2 and a RH of 55±5%. Kentucky bluegrass seeds were cultivated in 50 cm high box measuring 40×30 at the top and base. The boxes were filled with two different media. 1 :) sand (100%) 2 :) sand (S) (75%) + clinoptilulite zeolite (CZ) (15%). Following table (Table 1) show the Physical, chemical properties, and particle size of S and CZ medium.

Table 1: Physical and chemical properties of clinoptilolite zeolite-amended sand (CZ-sand) and sand used in the greenhouse experiment

Property		CZ-sand[a]	Sand
Hydraulic conductivity, cm h-1		40.51	39.57
Total porosity, % (by v)		46.92	43.41
Water availability, %		12.40	6.38
(between -0.003 and -0.1 MPa)		34.13	36.53
Aeration porosity, % (at -0.003 MPa)			
Bulk density, g cm-3		34.01	36.51
Particle density g cm-3		1.38	1.48
CEC		2.49	2.68
pH		15.59	0.08
Particle density g cm-3		6.8	5.7
		2.59	2.61
Particle size analysis			
mm		% (w/w)	
Gravel	>2	0	0
Total sand	2 - 0.05	97.3	98.0
Very coarse	2 - l	3.2	0
Coarse	1 - 0.5	5.9	3.9
Medium	0.5 - 0.25	65.1	69.6
Fine	0.25 - 0.1	21.0	22.5
Very Fine	0.1 - 0.05	1.8	1.8
Silt	0.05 -0.002	0.3	0
Clay	< 0. 002	2.7	2.2

[a]Sand amended with 15% clinoptilolite zeolite (v/v).

Salinity Treatment

After 3 month establishment period of turf in the boxes, three salinity treatments were imposed by saline irrigation waters, along with the control which was watered with tap water with an electrical conductivity (EC) value of 0.24 dS.m^{-1}. Saline irrigation waters were prepared by adding NaCl/$CaCl_2$ to tap water to obtain EC value 3.4 and 6.4 dS.m^{-1}. About 700-800 mL of solution was applied daily to each box by hand. This volume was adequate to ensure a 20% leaching fraction. All irrigation treatments were continued for 6 months (26 weeks). The following were recorded: Average content of minerals (Mg^{++}, Na^+, Ca^{++}, K^+) in the leachate and (Mg^{++}, Na^+, Ca^{++}, K^+ NH_4^+ and NO_3^- in root zone media, Visual turf quality, Photosynthetic rate (PR), transpiration, stomatal conductance (*gs*), Mesophyll efficiency (ME) and water use efficiency (WUE), maximum assimilation rate (A_{max}) and carboxylation efficiency (g_m). After 3th months and in selected time, root-zone media at 15 cm depth was collected from each treatment for Mg^{++}, Na^+, Ca^{++}, K^+, NH_4^+ and NO_3^- analysis. Nitrate and NH_4^+ was analyzed by kjeldahl method and rapid flow analyzer (modele303, alpkem crop) respectively, potassium and sodium (by flame photometer) calcium and magnesium (by atomic absorption). Visual turf quality was rated on a 0-9 scale, where 0=brown, dead turf; 6=acceptable quality for home lawn; 9=optimum color, density and uniformity (Torgeon, 2002). The clipping were collected at 3 weeks and dried at 70 C for 48 h for determine clipping yield, which was expressed in grams of shoot dry weight per each box. Photosynthetic rate, transpiration, and stomatal conductance were measured by portable photosynthesis meter (Lci, ADC, and England). Mesophyll efficiency and water use efficiency were calculated by dividing the photosynthesis by sub-stomatal CO_2, and by dividing the photosynthesis by transpiration, respectively (Liorens *et al.* 2003). Chlorophyll content was determined by spectrophotometer (Saini *et al.* 2001). The photosynthetic rate of leaves at ambient co_2 concentration (A_{360}) was measured between 9 and 13 o'clock at light saturation (temperature: 22-25 C; humidity: 20-28 mbar). Maximum assimilation rate (A_{max}) and the carboxylation efficiency (g_m) were calculated from the saturation phase and the slops of the linear phase of the A/C_i curves, respectively. A/C_i curves were measured by portable promoter type CIRAS-1 (PP systems, hitchin, herts. UK).

Data analysis

The experiment design consist of three salinity treatments and 4 root zone treatments (sand, sand with 5%, 10% and 15% clinoptilolite zeolite) replicated 4 times in a split-design with salinity treatment levels as main plot factor root zone media as subplot factor. All data were analyzed with MSTAT (Michigan State Univ., 1988) to detect differences among treatment effects. Means were compared with Duncan new multiple range test (DNMRT) at a 95% probability level.

Results and discussion

Turf quality

Saline irrigation reduced turf quality compared with the control. Amendment of sand with CZ increased turf quality during thirth month after saline treatment at both salinity levels. High rate of turf quality were observed at the presence 15% of CZ (Table 1). The beneficial effects of CZ on turf quality had diminished after 3th month of treatment. Enhance turf quality at the presence of CZ during early stage of salinity treatment may have occurred because: 1) CZ retained $NH4^+$ and K^+ in structural channels of the mineral, which could have improved turf quality and growth (Hung and Petrovic, 1994). Zeolite has two method of holding cations such as ammonium and plant nutrients. The first method is by absorption in its porous matrix. The second method is by cation exchange capacity (CEC). zeolite holds ammonium and other plant nutrients in the crystal structure where they are not water-soluble but are plant accessible on as needed time release bosis zeolite has a high affinity for the ammonium ion. This is a plant usable form of nitrogen the introduction of zeolite to the soil has the added benefit of increasing water retention, holding the nitrogen and other micro nutrients in the growth zone, providing a medium for the future capture of nitrogen, increasing the ion exchange capacity of the soil and enhancing infiltration and aeration of the soil (Minato, 1968) 2 :) CZ adsorbed Na and served as a buffering medium to prevent excessive Na uptake, thereby reducing Na toxicity to the plant; 3) both, however rising Na levels, might have diminish the long time the beneficial effect of CZ as CEC cites become more saturated with Na.

Table 2: Effects of Clinoptilolite Zeolite on turf quality of Kentucky bluegrass irrigated by three levels of saline irrigation water in selected time

Salinity (EC) of irrigation water (dS.m^{1})	Root zone treatment	Turf quality* (weeks after initial salinity treatment)												
		2^{z}	4	6	8	10	12	14	16	18	20	22	24	26
Control	Sand	8.2a^{X}	8.4a	8.2b	8.1b	8.3b	8.1b	8.1b	8.4b	8.1b	8a	8.1a	8a	8.2a
	CZ$_1$	8.2a	8.4a	8.5a	8.6a	8.7a	8.8a	8.7a	8.3b	8.6a	8.1a	8.1a	8a	8.1a
	CZ$_2$	8.4a	8.3a	8.7a	8.8a	8.8a	8.6a	8.7a	8.7a	8.6a	8 a	8.2a	8a	8.1a
	CZ$_3$	8.4a	8.5a	8.8a	8.8a	8.8a	8.7a	8.7a	8.8a	8.6a	8 a	8.1a	7.7a	7.8a
S$_1$	Sand	6.2c	5.6c	5.3b	5.4b	5.5b	5.3b	5.3b	5.2a	4.9a	4.2a	3.3a	3.1a	3.2a
	CZ$_1$	7.1ab	7ab	7.6a	7.7a	7.1a	7a	6.1a	5.2a	6.1a	4.5a	3.1a	3.1a	3.1a
	CZ$_2$	7.6a	7.2a	7.7a	7. 6a	7.4a	7.3a	6.1a	5a	5a	4.3a	3.2a	3.3a	3.3a
	CZ$_3$	7.6a	7.6a	7.8a	7.8a	7.5a	7.5a	6.4a	5.1a	4.8a	4.1a	3.2a	3.1a	3a
S$_2$	Sand	5.8b	5.5b	4.8c	4.6c	4.1c	4.2c	4.4c	4.2b	4.2a	2.4a	2.2a	2.3a	2.2a
	CZ$_1$	7.1a	7.2a	6.5ab	6b	5.1b	5.1ab	5.1ab	4.3b	4.5a	2.1a	2.2a	2.2a	2.1a
	CZ$_2$	7.1a	7.1a	6.9a	6.3ab	5.4b	5.2ab	5.2ab	5.2a	4.5a	2.2a	2.1a	2.2a	2.2a
	CZ$_3$	7.4a	7.1a	7.2a	7a	6.8a	6.8a	5.8a	5.4a	4.6a	2.4a	2.1a	1.7a	1.2b

*Turf quality was rated on a 0-9 scale (0 = dead and brown) (9 = best)
^{X}Different letters within a column indicate significant differences at the 5% level by Duncan new multiple renge test (DNMRT) at a 95% probability level. Lower case letters indicate mean among separation among root zone within salinity levels.
Z: Weeks after salinity treatment

Maximum assimilation rate (A$_{max}$), Carboxylation efficiency (g$_m$) and Net assimilation rate (A$_{360}$)

Salinity significantly reduced gs and A$_{max}$ in all salinity treatments (Table 2). In CZ treated plants gs and A$_{max}$ were increased until 3 month after salinity treatment. After 3 months A$_{max}$ and g$_m$ were decreased. This result indicates CZ ability to dereaseing salt effect is limit. A/ci–curves indicated that the salinity treatments (S1 and S2) reduced significantly Amax and gm. A$_{max}$ is a measure of the limitation of the net photosynthesis rate under the saturation and none limiting CO2 concentration (light reaction of photosynthesis), while g$_m$ reflects the activity of ribulose-1,5-biphophate caboxylase/oxygenase (rubisco), an essential enzyme for the Calvin cycle. The reduction of gm was in S2 was higher than S1 in sand base medium. Also, the same resalts were obtained inreduction of A$_{max}$ in sand base medium. On one hand this indicates that photosynthesis in S2 was more affected than in S1 and in the other hand it show that the dark reactions of photosynthesis were relatively more impaired by salinity than light reactions. (Miteva et al., 1992) reported that salinity inhibit the synthesis of total soluble protein with more pronounced inhibition of Rubisco synthesis. The net photosynthesis rate (A$_{360}$) reflected the changes in gm and Amax. Our result showed a significant decrease in S2 salt level after third month of salt application.

Table 3: Effect of CZ on maximum assimilation rate (A$_{max}$), carboxylation efficiency (g$'_{m}$)and net assimilation rate measured at ambient Co$_2$ concentration (A$_{360}$) of Kentucky bluegrass leaves irrigated with three salinity levels of saline water 1 to 5 months after initial salinity treatment.

Salinity (EC) of irrigation water (dS.m^{1})	Media	A$_{max}$ (µmol/m²/s)					g$'_{m}$ (µmol/m²/s)					A$_{360}$ (µmol/m²/s)				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Control	Sand	25b	24c	24c	25.8b	24b	138d	139c	136c	138b	136a	12a	12a	12.2a	12.3a	12a
	CZ$_1$	25.8b	26b	26b	24.9b	24b	142c	140b	140b	140b	138a	13a	13a	13.2a	12.9a	12a
	CZ$_2$	26.9b	27b	26.6b	26.1b	25b	148b	150a	147a	148a	141a	13.8a	13.5a	13a	13.1a	13a
	CZ$_3$	29a	29.1a	28.8a	28a	28a	152a	153a	152a	150a	148a	15a	14.2a	14.5a	14a	14a
S1	Sand	23b	22b	22d	20b	15b	100d	100c	99c	98c	89b	12a	11a	11.2a	11.2a	10a
	CZ$_1$	24.8b	23b	24c	21b	17b	142c	140b	140b	140b	138a	13a	13a	13.2a	12.9a	12a
	CZ$_2$	24.9b	27a	26.6b	19.1b	16.1b	148b	150a	147a	144b	141a	13.8a	13.5a	13a	13.1a	13a
	CZ$_3$	28a	27.1a	28.8a	29a	27a	152a	153a	152a	153a	148a	14.1a	14.2a	14.5a	14a	14a
S2	Sand	17d	16d	16d	15a	14a	70d	68d	59c	57c	45b	9b	10b	9.9b	9.9a	9.5a
	CZ$_1$	23.8c	23c	22c	14.7a	13.3a	142c	140c	140b	140b	138a	13a	13a	13.2a	10a	9.3a
	CZ$_2$	26.9b	27b	25.6b	14.3a	12.7a	148b	150b	147a	144b	141a	13.8a	13.5a	13.4a	9a	9a
	CZ$_3$	29a	29a	28.8a	13.1a	11a	152a	153a	152a	150a	148a	14a	14.2a	14.5a	9a	8a

^{X}Different letters within a column indicate significant differences at the 5% level by Duncan new multiple renge test (DNMRT) at a 95% probability level. Lower case letters indicate mean among separation among root zone within salinity levels.
Z: Weeks after salinity treatment

Mesophyll Efficiency (ME), Water Use Efficiency (WUE) Photosynthetic Rate (PR) and Stomatal Conductance (SC)

The significance of salinity for the agronomical and physiological aspects of plants in enormous. Accumulation of both Na^+ and Cl^- in the roots and aerial part of plants depend on plant specious can inhibit or reduce PR. The reduction of PR in the salinity treated plant reported by many researchers. In our experiment salinity reduced significantly PR and maximum reduction was observed in S_2 in sandy medium. Adding CZ prevent the reduction of PR. But, evaluation of data in the end of experiment showed CZ content medium have reduction in PR. The maximum rate of SC and PR was observed at presence of 15% CZ in all salinity irrigation treatments in early stage of salt application. Increasing PR and SC at the presence of CZ reported by some authors (Abdi et al., 2006). Also the same result was accrued about WUE and ME. Presence of zeolite in medium prevents decreasing PR, SC, WUE and ME at both salinity levels (Table 4). In this study, zeolite increased photosynthesis rate, which was probably due to availability of elements by zeolite and also available water for plants. Nitrogen deficit in kiwifruit cause reduce photosynthesis rate by 50% (Smith and Buvalda, 1998). Sufficient potassium and water resulted in opening stomata and increasing stomatal conductance that increased photosynthesis rate, mesophyll efficiency and water use efficiency. Shoot and root dry and fresh weights of radish were significantly increased by the combination of nitrogen and zeolite with compared to use of nitrogen alone (Lewis et al., 1980).

Table 4: Effect of CZ on Photosynthesis rate (PR), Mesophyll efficiency,water use efficiency (WUE), Stomatal conductance (SC) of Kentucky bluegrass leaves irrigated with three salinity levels of saline water in selected time

Salinity (EC) of irrigation water (dS.m^{1})	Media	Photosynthesis rate (µmol m^{-2}s^{-1})			Stomatal Conductance (mol m^{-2}s^{-1})			Mesophyll efficiency (µmol m^{-2}s^{-1}/vpm)			Water use efficiency (µmolm^{2}s^{1}/mmolm^{-2} s^{-1})		
		2^{z}	4	6	2	4	6	2	4	6	2	4	6
Control	Sand	21.4c	21.3c	21.1b	0.68b	0.65b	0.67b	31.47b	31.7b	31.49b	20.4c	21.3b	21.8b
	CZ_1	28.6b	29b	29.5a	0.78a	0.75a	0.76a	36.66a	39.33a	38.82a	29.6b	29.6a	29.4a
	CZ_2	28b	29b	29.6a	0.78a	0.75a	0.77a	35.89a	39.33a	38.44a	29.7b	29.7a	29.6a
	CZ_3	35a	32a	32.1a	0.86a	0.88a	0.81a	40.69a	37.5a	39.62a	34.1a	33a	32.11a
S_1	Sand	18c	16b	16b	0.52c	0.51b	0.51a	34.61a	31.37a	31.37a	17.1a	16.21b	16.28b
	CZ_1	25b	22a	22a	0.75b	0.72a	0.69a	33.33a	30.55a	31.88a	24b	22a	22a
	CZ_2	23b	22a	22a	0.75b	0.66a	0.69a	30.66a	30.55a	31.88a	24.8b	21.7a	21.7a
	CZ_3	26a	19a	20a	0.87a	0.62a	0.63a	29.88a	30.64a	31.76a	27.8a	19.7a	19.7a
S_2	Sand	12c	13a	12.3a	0.47b	0.43a	0.44a	25.53b	30.23b	30.23a	12.1b	12.7a	12.2a
	CZ_1	23b	13.1a	9.2b	0.71a	0.58a	0.34b	32.39a	24.71b	24.71c	23.4a	13.8a	9.11b
	CZ_2	24b	13.7a	11b	0.71a	0.42a	0.37b	33.8a	32.61a	29.72b	24.1a	13.9a	11b
	CZ_3	26a	10.1a	5.3c	0.84a	0.36b	0.23c	30.23a	28.08b	23.04c	26.3a	10.21b	5.32c

^{X}Different letters within a column indicate significant differences at the 5% level by Duncan new multiple renge test (DNMRT) at a 95% probability level. Lower case letters indicate mean among separation among root zone within salinity levels.

^{Z}Month after initial salt application

Root zone analysis

All extractable minerals (Table 5) in the control irrigation were higher in CZ content medium. This result reflects the high CEC of zeolite. As increasing salinity Na concentration in media containing CZ were increased. While Mg concentration decreased with increasing salinity during experiment. As increasing salinity from 3.5 dS.m^{-1} to 6.5 dS.m^{-1} the concentration of Na increased at the presence of CZ. Maximum rate of Na observed in CZ_3 treatment at high level of salinity (S_2). Also Ca content of root zone media decreased with increasing salinity level to 4 and reached to plateau at high salinity. Mg content decreased with increasing salinity. Sodium absorption ratio increased linearly with increasing salinity level. Highest SAR value was observed in high salinity level of CZ treatment in the end of experiment. Amendment sand with CZ increased SAR value by 0.18 to 1.08 units under control irrigation, and. 0.73 to 2.33 and 1.04 to 7.55 unit in S_1 and S_2 respectively after 3 months. Evaluation of SAR value (data not shown) in the end of experiment showed SAR value by 0.23 to 1.17 units under control irrigation, and. 1.08 to 4.54 and 1.56 to 13.12 unit in S_1 and S_2 respectively. Increasing in SAR value may associated with the preferential retention of Na^+ over Ca^{++} or Mg^{++} or both. Our result showed that CZ under salinity condition did not have best efficiency. The fact that CZ exhibited higher Na in the leachate under nonsaline, but retained more Na under saline conditions, suggests that zeolite can act as both a source and sink for Na. this result associated with finding of Qian *et al*, 2001. The beneficial effect of CZ as soil amendment under saline condition was observed for 3 months. Leachate and root zone soil analysis suggests that, with long-term use of saline irrigation water, zeolite can increase the potential of sodicity and salinity problem.

Results indicated that the amount of K^+ increased when zeolite was applicated in soil. Increasing the amount of K^+ in soil showed that zeolite had potential to adsorb K^+ from chemical fertilizer and reduce it from leaching. It was reported that zeolite showed prominent as slow-release potassium (Carolino *et al*., 1998). Similar effect was found in calcium and magnesium. This result was agreement with those of (Mazur et al., 1986) who pointed out that zeolite improved calcium and magnesium in the soil. This result indicate zeolite can play important role in increasing fertilizer efficiency and improving minerals uptake in none saline condition.

Table 5: Effect of CZ on ion concentrations of in leachates collected from box containing Kentucky bluegrass irrigated with three salinity levels of saline water 2 and 6 month after initial salinity treatment

Salinity (EC) of irrigation water $(dS.m^1)$	Media	Ion (mg L^{-1})											
		2^z						6					
		Na^+	Ca^{++}	Mg^{++}	K^+	NH_4^+	NO_3^-	Na^+	Ca^{++}	Mg^{++}	K^+	NH_4^+	NO_3^-
Control	Sand	12b^x	172c	41b	33b	12b	13.5b	13b	166c	26b	29b	4b	0.5b
	CZ_1	115a	788b	108a	509a	58a	22a	109a	569b	75a	438a	25a	7.1a
	CZ_2	119a	808a	108a	514a	58a	23.1a	108a	573a	75a	444a	29a	7.5a
	CZ_3	121a	801a	109a	525a	55a	23.8a	112a	573a	76a	452a	30a	8.1a
S_1	Sand	48b	182c	21b	32b	4.2b	12.5b	68c	278b	19b	42b	2b	2.6b
	CZ_1	315a	1130b	98a	697a	38a	32a	475b	738a	65a	614a	34a	3.4a
	CZ_2	317a	1219b	98a	708a	40a	31a	481b	738a	66a	612a	35a	3.42a
	CZ_3	319a	1258a	103a	718a	41a	33a	492a	744a	66a	614a	38a	3.58a
S_2	Sand	59c	208b	21b	26b	2.21b	8.9b	96c	269b	14.2b	29.2b	3b	0.41b
	CZ_1	840b	878a	75a	698a	70a	28a	1358b	759a	56a	788a	75a	1.29a
	CZ_2	851b	875a	76a	690a	72a	29a	1365b	741a	54.2a	789a	73a	1.44a
	CZ_3	869a	875a	76a	690a	78a	29a	1376a	770a	59a	785a	78a	1.8a

^{Z}Months after initial salt treatments.

^{X}Different letters within a column indicate significant differences at the 5% level by Duncan new multiple renge test (DNMRT) at a 95% probability level. Lower case letters indicate mean among separation among root zone within salinity levels.

Ion composition in the leachates

Results showed significant different ion composition of leachate among treatments. Under control irrigation K concentration in leachate in all CZ treatment lower than S and lowest rate of K concentration observed in CZ_3. This result indicates that CZ retains more K than S, supporting the finding of Fergusen et al., 1986 (Table 6).

Evaluation Na concentration in control irrigation showed Na was higher for CZ content medium than S in initial stage of salt application. Observation after 4 months showed Na content was more for CZ content medium than S in control irrigation. This result showed zeolite contained higher Na content. The same results were observed Ca in control irrigation. Sodium concentration under control irrigation was highest for CZ_3 and lower for S. Concentration of Na and Ca in leachates increased dramatically as salinity increased for all root zones. This result may be due to composition of saline solutions that used for this study (equal equivalent weights of Ca and Na). The concentration of Na and Ca were strongly influenced by soil amendment type. Adding zeolite reduced leaching of Na and increased leaching of Ca and Mg at both salinity levels. Our result indicate that zeolite is more selective for Na and less selective for Ca and Mg which may be related to the size and change of the cation and the specific crystal structure and distribution of the exchange sites in zeolite. Also, K concentration extremely influenced by type of medium and salt application. As increasing salinity, K concentration in leachate was increased. This result show the depress effect of high Na levels on K uptake, thereby increasing leaching of K. This is agreement with another study (Qian et al., 2000). Results indicated that the amount of mineral elements including N, K, CA^{++}, MG^{++} in soil were intensely influenced by zeolite application and increased. Hung and Petrovic (1995) reported that the application of zeolite improved nitrogen efficiency about 16 to 22 percent. Furthermore, zeolite reduced the leaching of ammonium and nitrate up to 86 to 99 percent.

Table 6: Effect of CZ on ion concentrations of in leachates collected from box containing Kentucky bluegrass irrigated with three salinity levels of saline water 2 and 4 month after initial salinity treatment

Salinity (EC) of irrigation water ($dS.m^1$)	Media	Ion ($mg L^{-1}$)							
		2^z				6			
		Na^+	Ca^{++}	K^+	Mg^{++}	K^+	Ca^{++}	Na^+	Mg^{++}
Control	Sand	5 b^x	12b	52a	4.2b	25.1a	22b	5.4c	4.2
	CZ_1	15.3a	64.1a	3.5b	6.9a	3.5b	34a	9.9 b	4.33
	CZ_2	15.61a	67.8a	3.4b	6.5a	3.81b	35a	11.3a	5.31
	CZ_3	16.5a	68a	3.2b	6.5a	4.1b	36a	11.3a	5.33
S_1	Sand	520a	300b	108.1a	10.1b	25a	428c	478a	16.2b
	CZ_1	50b	751a	8.1b	86a	8.3b	621b	45.1b	77.3a
	CZ_2	50b	753a	8.51b	86a	8.4b	688a	48b	79a
	CZ_3	56b	758a	8.2b	90a	8.8b	709a	50.7b	84.2a
S_2	Sand	1358a	874b	113.4a	7.4b	16.9a	1180	1193a	9.9c
	CZ_1	60b	1590a	9.9b	100a	13.4b	1664	69b	98.4b
	CZ_2	69b	1609a	9.9b	103a	12.2b	1673	68.2b	109a
	CZ_3	69b	1619a	9.3b	106a	12.2b	1762	76b	107a

^{Z}Months after initial salt treatment

^{X}Different letters within a column indicate significant differences at the 5% level by Duncan new multiple range test (DNMRT) at a 95% probability level. Lower case letters indicate mean among separation among root zone within salinity levels.

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