Asian J. Turfgrass Sci. 25(1):79~88, 2011

Effects of Salinity Level and Irrigation Rate on Kentucky Bluegrass (*Poa pratensis* L.) Growth and Salt Accumulation in Sand Growing Media Established Over the Reclaimed Saline Soil

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ABSTRACT. The purpose of this study was to obtain information on rates and salinity levels of irrigation for growth of Kentucky bluegrass by minimizing the hazard of salt accumulation in the sand based growing medium. Root zone profile consists of 20 cm sand based top soil, 20 cm of coarse sand as layer to interrupt capillary rise and 10 cm of reclaimed paddy soil as a base of the root zone profile. Topsoil was a mixture of dredged sand and peat with a ratio of 95%: 5% by volume. The columns were soaked into 5 cm depth saline water reservoir with salinity level of 3-5 dSm^{-1}. Salinity levels of irrigation water were 0, 2 and 3 dSm^{-1}. Irrigation rates were 3.8, 5.7 and 7.6 mm day^{-1} which were equivalent to 70%, 100% and 130% of average ET (evapotranspiration) rate of Kentucky bluegrass, and irrigation interval was 3 days. Salt accumulation was due to irrigated water and moved up water from shallow water base. At the end of second year, the accumulation of salt in the rootzone showed ECe of 3.86, 4.7 and 5.1 dSm^{-1}, and SAR of 19.2, 23.9 and 27.5 when the salinities were 0, 2 and 3 dS m^{-1}, respectively. Irrigation rates of 100% and 130% of ET rate with saline water did not decrease ECe and SAR in growing media. The growth of KBG was influenced by irrigation rate in the 1st year, however, salinity level was more critical in the 2nd year. Compared to non-saline water, saline water of 2 and 3 dS m^{-1} resulted in decreased visual quality by 3.2% and 16.5%, by 6.4% and 39.3% in clipping weight, and by 5.5% and 5.0% in root mass, respectively.

Key words: EC, ET, Irrigation rate, Kentucky bluegrass, Salinity, Salt

Introduction

Irrigation for turfgrass was considered as low priority in using fresh water (Kjelgren et al., 2000; Marcum, 2006). Saline water can be used as turfgrass irrigation source if the growing media are sandy and high in permeability (Silvertooth, 2005). High sand content of root zone provides the ability to resist soil compaction from frequent foot traffic, rapid drainage, improve aeration for root growth, deep rooting, minimizing disease pressure and protection against salt problems (Beard, 1973; Freddie et al., 2003; MacCoy, 2006). Since sand cannot retain enough water, sand based growing media in golf course should include a coarse sub layer to form sub-ground water table. Effect of a coarse layer on increasing water retention in the top soil depends on the particle sizes of layers and the sharpness of the boundary (Miller, 1969). As the particle size differential between the layers increase, the amount of water retained in the finer upper layer also increase (Waddington et al., 1992). However, the amount of water retained in the rootzone was affected by the rootzone properties and the coarseness of the underlying layer (Taylor et al., 1993). Irrigation with saline water might also cause the decline of turf quality (Qian and Suplick, 2001). Salt accumulation in growing media is affected by volume of water, water movement by infiltration, percolation and drainage, and ET pattern (Silvertooth, 2005). Drainage is an essential factor in dealing with salt and sodium accumulation (Gross, 2008).

Salinity can cause many problems in turfgrass growth by imposing ion and osmotic stresses on plants (Tester and Davenport, 2003). Increased salinity can also be responsible for the root/shoot ratio, where shoot growth decreased linearly in all classes of salinity, while root growth increased to a maximum point and then declined (Harivandi et al., 1992). Clipping yield of Kentucky bluegrass is influenced by salinity, cultivar and their interaction, and average weekly clipping yield decreased linearly with increasing salinity (Qian et al, 2004). Marcum (2006) reported that the growth of Kentucky bluegrass was reduced by 50% when the EC of the irrigation water was 3 dS m^{-1}. Turfgrass have compensatory adaptive mechanism to osmotic water and nutrient stress under saline conditions, such as enlargement of its surface for irrigation water absorption, thus increasing its root biomass (Harivandi et al., 1992). Turfgrass needs specific level of irrigation for desired aesthetic function. Different levels of irrigation can lead to different ET and

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Received : April 15, 2011, Revised : May 4, 2011, Accepted : May 13, 2011

different quality of turfgrass (Bastug and Buyuktas, 2003). Xinmin et al. (2007) confirmed that Kentucky bluegrass has maximum annual ET of 802.3 mm and minimum of 747.9 mm. Ebdon et al. (1998) found that the ET range of Kentucky bluegrass is 5.36 - 6.82 mm d^{-1}. In other cases, irrigation using 100% ET to maintain turfgrass quality is not necessary (DaCosta and Huang, 2006). Kentucky bluegrass is reported to require 80% of pan evaporation to maintain its quality (Wilhelm et al., 2010). The quality of Kentucky bluegrass decreased about 10% with irrigation schedule of up to 27% ET deficit (Feldhake et al., 1984). ET of turfgrass can be estimated by multiplying reference crop ET (ET0 potential) and crop coefficient (Kc). Brown, (2000) defined reference ET (ET0) as the ET from 3-6 inch tall cool season grasses that completely cover the ground being supplied with adequate water. Degree of water deficiency can be estimated by comparing turfgrass ET and the available precipitation data. Cool season grass with 4 - 5 cm mowing height has Kc of 0.65, while cool season with 2 - 2.5 cm mowing height has Kc of 0.72.

Reclaimed soil in Korea is saline-sodic and has a shallow water table. Shallow saline water table can cause not only direct problem of the turfgrass growth, but also salt accumulation through capillary rise. Sodic soils generally exhibit poor physical condition, such as forming impermeable surface seal, and decreasing hydraulic conductivity of soil profile (Shainberg et al., 1989). Saline–sodic soil contains large amount of total soluble salt and sodium is more than 15% of total exchangeable salts and the pH is higher than 8.5 (Mzezewa et al., 2003). Rahayu et al. (2010) reported that the largest accumulation of salt in the spring with electrical conductivity in saturated extract (ECe) of 5.4 dS $m^{-1}$and sodium absorption ratio (SAR) 34.0 in growing media without the interruption layer for capillary rise and ECe of 4.6 dS $m^{-1}$and SAR 8.24 at the sand based growing media using gravel as the interruption layer for the capillary rise material at saline condition in Korea. Electric conductivity (ECe) of reclaimed soil without capillary water interruption layer ranged from 1.8 dS m^{-1} to 9.4 dS m^{-1} (Kim et al, 2009)

Materials and Methods

Root zone profile was packed in 30 cm diameter columns with 20 cm top soil, 20 cm capillary interruption layer and 10 cm of reclaimed paddy soil (RPS) as the bottom layer of the profile. The top soil is the dredged-up sand from Bhunam Lake in Korea and mixed with 5% peat by volume. Columns were made by cutting 30 cm diameter pipe into 50 cm length, and attached the plastic net at the bottom. Columns were placed in the reservoirs of 5 cm depth saline water as a saline water table. Water level and salinity were maintained by frequent addition. The RPS was the native top soil of Seosan B reclaimed area in Seosan City, Korea. The saline water from the sea of Seosan City was diluted by adding tab water until it reaches the salinity of 2 dSm^{-1} and 3 dSm^{-1} for irrigation and 3-5 dSm^{-1} for base water reservoir. To block the capillary raise, an interruption layer was installed with coarse sand > 2 mm. Kentucky bluegrass in blend of cultivars of Midnight, Unique, and Challenger were used.

Experiment was conducted at Dankook University turfgrass field in Cheonan, Korea from June 2009 to October 2010. Columns were arranged by completely randomized deigns with 3 replications. Turfgrass was irrigated by fresh water during one month, and then was followed by salinity and irrigation rate treatments. Salinity levels of irrigation water were non saline (NS) with ECw of 0.0- 0.1 dSm^{-1}, medium saline (MS) with ECw of 2.0 dSm^{-1} and high saline (HS) with ECw of 3.0 dSm^{-1}. Chemical characteristics of saline irrigation water were summarized as table 1. Irrigation rates were 800, 1200 and 1600 ml/column by 3 days interval (equivalent to 3.77, 5.66 and 7.55 mm day^{-1}). Based on Ebdon et al. (1998) that average ET of Kentucky bluegrass was 5.36 - 6.82 mm day^{-1}, the irrigation rates were relevant to 70%, 100% and 130% of ET rate. Complete fertilizer (11-5-7) was applied 3 times per year, with 4 g N m^{-2} per each application. Fertilizer was applied at the initial establishment of sod, and then was followed by 2 months interval. Insecticide and fungicide were applied when the turfgrass showed early symptoms of insect threat or disease. Experimental area has dry period from April to June and September to October of 2009, and from April to June and October to November, 2010. Wet period of Cheonan was July to August of 2009 and July to September of 2010, respectively.

Visual quality, clipping dry weight, soil water content, root length, and root dry weight were measured. Chemical characteristics of soil pH, ECe, and SAR were also investigated. Moisture contents were measured every 1 day, 2 days and 3 days after irrigation with Time Domain Reflectometry (TDR). Turfgrass was mowed every week and the clipping was collected. Clipping dry weight was measured after drying at 100°C for 24 hour in dry oven (model; DNC-122sp). Visual quality of turfgrass was evaluated every week by considering color, uniformity, density and ground coverage. Root length and root dry

Table 1. Chemical characteristics of irrigation water used in this experiment.

Irrigation water	Ca (ppm)	Mg (ppm)	Na (ppm)	ECw (dSm^{-1})	SAR
Non Saline	25.1	6.1	5.7	0.2	0.4
Medium saline	52.1	86.3	231.2	2.0	6.3
High saline	63.1	102.1	448.2	3.0	11.7

weight were measured every season, using soil sampler. Root dry mass was measured by washing the core, cutting thatch layer away and drying at 100°C for 24 hours. Soil moisture content was measured using TDR with HiClay option. The HiClay option has correlation of Y=0.132x + 6.745, R^2= 0.025; while drying oven water content (in 100°C for 24 hours) has correlation of Y= 0.211x + 10.79, R^2= 0.025. Soil pH was measured using pH meter (pH-220L) with ratio of soil: water (1:5). Electric conductivity was measured by conductivity meter (Cond 720). ECe was calculated using texture class conversion factor from ECp data (Carrow and Duncan, 1998). SAR was calculated by analyzed the Ca, Mg and Na. Calcium and Mg were analyzed by using 2 steps. First step was to remove the Ca and Mg from soil complex by ammonium acetate method. Total of hardness (Ca + Mg) were analyzed by 10 ml of extract solution buffered by 5 ml ammoniac buffer (pH 10). Color indicator was eriochrome black T solution and titration of solution was by 0.01 M EDTA. Subtracting the Ca in ppm from total of hardness was Mg (Hach, 1996; Austin, 2005). Sodium was calculated by soil conductivity (ECe) data in dSm^{-1} multiplied by 10 and then subtracted by Ca and Mg content (Hach, 1996). Data were analyzed by SAS to provide the statistical significance.

Results and Discussion

Salt accumulation

Soil moisture content was increased as irrigation rate and salinity level of irrigation increased. Soil moisture contents in fall season were generally higher than in spring and summer season (Table 2). Irrigation using by 3 dSm^{-1} saline water with 130% irrigation rate resulted in higher soil moisture content than 70% irrigation rate of ET by the spring of 2010. This results suggest that high saline irrigation water decreased soil water potential and resulted in higher soil moisture content. Lee at al. (2005) reported that soil water potential decreased due to high salinity in saline sites. High soil moisture content may be caused by the soil permeability decrease due to salt accumulation (Hillel, 1990). Soil moisture content at 3 days after irrigation was increased as salinity level of irrigation increased, from 2009 to the summer of 2010. Irrigation using 70% of ET rate with 2 dSm^{-1} and 3 dSm^{-1} saline water increased soil moisture contents by 49.5% and 95.2% respectively, when compared to non saline irrigation. Irrigation using 100% of ET rate with 2 and 3 dSm^{-1} saline water increased the soil moisture content by 35.4% and 102.6%, while 130% of irrigation rate caused increases by 57.3% and 156.7%, respectively when compared to non saline irrigation. Thompson et al. (2007)

Table 2. Moisture content of growing media with various salinity level and irrigation rate.

Irrigation treatments		Year 2009						Year 2010					
Salinity level	Irrigation rate	Summer 2009			Fall 2009			Spring 2010			Summer 2010		
		1 day	2 day	3 day	1 day	2 day	3 day	1 day	2 day	3 day	1 day	2 day	3 day [z]
dSm^{-1}	% ET	Moisture content (%)											
0.0	70	4.68 e	3.98 e	3.49 c	5.54 e	4.69 c	4.10 e	5.68 c	5.20 c	5.04 d	4.63 b	4.55 c	4.55 d[y]
	100	5.10 e	4.11 de	3.47 c	5.85 de	5.00 c	4.33de	6.13 bc	5.48 c	5.10 d	4.86 b	4.54 c	4.58 d
	130	6.42 d	4.89 c	4.04 ab	5.98 de	5.12 c	4.65 d	6.59 bc	5.90 bc	5.54 cd	5.55 b	5.03 c	4.85 cd
2.0	70	6.68 cd	4.71cde	3.76 bc	6.36 cd	5.83 b	5.56 c	7.95 bc	7.00 bc	6.48 cd	6.66 b	6.29 bc	6.80 bcd
	100	7.27 cd	4.94 cd	3.83 abc	6.98 b	6.10 b	5.93bc	8.24 bc	7.23 bc	6.31 cd	6.81 b	6.43 bc	6.20 bcd
	130	7.68 bc	5.11 bc	4.05 ab	6.94 bc	6.23 b	6.11 b	8.78 bc	8.11 bc	7.40 cd	7.75 b	7.49 bc	7.63 bcd
3.0	70	7.08 cd	5.26 bc	3.97 ab	7.28 b	6.25 b	6.19 b	9.89 b	8.80 ab	7.89 bc	8.79 b	7.91 bc	8.88 abc
	100	8.26 b	5.84 ab	4.03 ab	8.02 a	7.23 a	6.95 a	14.71 a	11.96 a	10.33ab	10.19 b	10.26ab	9.28 ab
	130	9.43 a	6.41 a	4.24 a	8.21 a	7.23 a	7.37 a	15.41 a	11.96 a	10.86 a	16.40 a	13.93 a	12.45 a
ANOVA													
Salinity level		**	**	*	**	**	**	**	**	**	**	**	**
Irrigation rate		**	**	*	**	**	**	*	ns	ns	ns	ns	ns
Saline vs rate		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

[z] day = days after irrigation.

[y] Means within a column followed by the same letter are not significantly different based on LSD.

Table 3. pH, ECe and SAR of growing media with various salinity level and irrigation rate over the reclaimed saline soil.

Irrigation treatments		Year 2009		Year 2010		
Salinity level	Irrigation rate					
dSm⁻¹	% ET	Summer	Fall	Spring	Summer	Fall [z]
		pH				
0.0	70	6.23 g	6.58 bc	6.97 e	6.04 e	6.60 d [y]
	100	6.33 f	6.51 c	6.98 de	6.49 c	6.54 d
	130	6.40 e	6.50 c	7.06 c	6.68 b	6.64 cd
2.0	70	6.65 d	6.75 a	7.11 b	6.14 de	6.78 bc
	100	6.74 c	6.68 ab	7.12 b	6.24 d	6.67 cd
	130	6.83 b	6.61 bc	7.18 a	6.74 b	6.95 ab
3.0	70	6.84 ab	6.66 ab	6.96 e	7.02 a	7.07 a
	100	6.85 ab	6.64 ab	6.95 e	7.04 a	6.98 a
	130	6.90 a	6.68 ab	7.02 cd	7.02 a	7.06 a
		ANOVA				
Salinity level		**	**	**	**	**
Irrigation rate		**	ns	**	**	*
Salinity vs rate		ns	ns	ns	**	ns
		ECe (dS m⁻¹)				
0.0	70	1.07 d	2.80 abc	3.87 d	1.7 c	4.18cd [y]
	100	1.09 d	2.28 d	3.89 d	1.6 c	3.98 d
	130	1.27 d	2.45 cd	3.83 d	1.8 c	4.05 d
2.0	70	3.09 bc	2.68 bcd	4.51 c	1.9 bc	4.48 bc
	100	3.33 abc	2.67 bcd	4.56 c	1.9 bc	4.95 a
	130	2.95 c	2.46 cd	4.60 bc	2.0 bc	4.82 ab
3.0	70	4.02 ab	3.01 ab	4.80 bc	2.2 ab	4.90 a
	100	4.09 a	3.13 a	5.31 a	2.0 abc	4.92 a
	130	3.49 abc	2.93 ab	5.07 ab	2.4 a	5.15 a
		ANOVA				
Salinity level		**	**	**	**	**
Irrigation rate		ns	ns	ns	ns	ns
Salinity vs rate		ns	ns	ns	ns	ns
		SAR				
0.0	70	1.4 d	14.4 a	18.5 d	7.4 bc	4.9 c [y]
	100	1.5 d	13.9 a	19.8 cd	5.9 c	7.1 bc
	130	2.1 dcd	14.6 a	19.3 cd	7.3 bc	6.6 bc
2.0	70	11.0 bcd	14.3 a	22.6 bcd	8.0 abc	9.0 ab
	100	11.6 bc	13.4 a	24.7 abc	7.3 bc	11.7 a
	130	9.4 bcd	13.7 a	24.2 abc	8.2 abc	10.7 a
3.0	70	15.7 ab	16.8 a	26.3 ab	10.2 ab	10.9 a
	100	23.2 a	17.3 a	28.1 a	8.2 abc	11.0 a
	130	13.9 ab	14.1 a	28.2 a	11.1 a	10.5 a
		ANOVA				
Salinity level		**	ns	**	**	**
Irrigation rate		ns	ns	ns	ns	ns
Salinity vs rate		ns	ns	ns	ns	ns

*,** Statistical significance at the errors of 5% and 1% by ANOVA.
[z] Observed at the end of every seasons.
[y] Means within a column followed by the same letter are not significantly different based on LSD (error=5%).

reported that relative increases of 4 to 7.5% in soil moisture content for each 1 dSm^{-1} increase of ECw. However, this result showed big difference of soil moisture content by treatments, suggesting that salt accumulation may be from saline irrigation as well as capillary rise of saline water table. Statistical analysis showed that salinity level, irrigation rate and their interaction affected the soil moisture content. Reducing capillary rise of saline water by sub layer might affect the degree of salt accumulation. Accumulation of salt in reclaimed soil may cause decrease in permeability and drainage, thus resulting in longer water stay in the top layer. Jorenush and Sepaskhah (2003) reported that the excess water leached the salts in the first layer and increased the salts content in the second layer. In the August of 2010 frequent rain caused longer water stay in the top soil in the 3 dSm^{-1} salinity treatments of all irrigation rates. At this time, turfgrass showed decreased clipping dry weight and quality.

Irrigation rate influenced the pH of rootzone, where pH decreased as the rate of irrigation decreased. The pH was decreased as salinity level of irrigation decreased in summer (Table 3). Saline irrigation resulted in higher pH than non saline irrigation in fall season. Irrigation using non saline and 2 dSm^{-1} saline with 130% irrigation rate resulted in higher pH than 70% irrigation rate in summer and spring, but resulted in even higher pH in fall season. Irrigation using by 3 dSm^{-1} saline water with 130% irrigation rate resulted in higher pH than 70% rate only in spring season. This result suggested that salinity level and rate of irrigation influence the pH of rootzone. Irrigation using non saline water increased the pH from the summer of 2009 to the spring of 2010, but decreased the pH in the summer of 2010. This trend was similar with the salts accumulation trend. Irrigation using by 3 dSm^{-1} saline water decreased the pH of rootzone in the fall of 2009, and then increased by the summer of 2010. Decrease of rootzone salinity by high rainfall in the summer of 2010 was not followed by decrease of pH in 3 dSm^{-1} saline irrigation. Difference in change of soil salinity and pH by saline irrigation may be related to the organic matter contents in the rootzone. Organic acid produced by peat decomposition might have affected the pH. Acidity of soil may be affected by organic acid, organic-mineral colloidal, and colloidal mineral (Sutanto, 1995). Salinity cause of the easy of soil organic matter due to solubility, decomposability and accessibility increase resulting in the increase of dissolved organic matter (Wong et al., 2006).

Electrical conductivity (ECe) of the rootzone was increased as the salinity of irrigation increased in spring and summer. The ECe in the rootzone was increased from the early stage to the spring of 2010. The ECe of growing media irrigated by non saline water was similar with of 2 dSm^{-1} saline water irrigation in the fall. This result suggested that the salt moved up from the water reservoir to the top soil. Irrigation using by 3 dSm^{-1} saline water resulted in higher ECe than 2 dSm^{-1} saline due to the salt accumulation from irrigation and capillary rise. Huck et al. (2000) reported that increasing salt accumulation typically occurs in late summer and early fall. However this study showed that salt accumulation from capillary rise did not occur in summer due to high rainfalls but significant salt accumulation during the spring and fall. The ECe of growing media in the summer of 2009 was 1.14, 3.12 and 3.86 dSm^{-1}, from non saline, 2 dSm^{-1} and 3 dSm^{-1} from saline irrigation, respectively. The ECe of spring period was higher than that of fall and summer. Increase of ECe from the summer of 2009 to the spring of 2010 by non saline irrigation was 339%, 146% by 2 dSm^{-1} saline irrigation and 131% by 3 dSm^{-1} saline irrigation. The ECe in the rootzone in the fall of 2010 showed 239%, 237% and 226% higher than summer by non saline, 2 and 3 dSm^{-1} saline irrigation, respectively. Statistical analysis showed that ECe was more affected by the level of salinity than by the amount of irrigation rate. Level of salt accumulation in soil depends on the volume of water applied, water movement such as infiltration, percolation, drainage and site ET pattern (Silvertooth, 2005).

Sodium adsorption ratio (SAR) in the rootzone increased as salinity level increased in summer. In fall season, there was no difference in SAR in all treatments. The SAR of growing media in the summer of 2009 was 1.7, 10.7 and 13.6 from non saline, 2 dSm^{-1} and 3 dSm^{-1} saline irrigation, respectively. Since SAR of spring was higher than fall and summer, there might have been salt accumulation. Accumulation of salt during the summer of 2009 to the spring of 2010 was 1150% by non saline irrigation, 223% by 2 dSm^{-1} saline water and 202% by 3 dSm^{-1} saline water. Based on these results, it may be understood that there was upward movement of salts from shallow saline water table that caused the salt accumulation. In the summer of 2010, most of salts were leached by rain. The SAR of growing media in the summer of 2010 was 6.87, 7.83 and 9.83 when irrigated by non saline, 2 dSm^{-1} and 3 dSm^{-1} saline irrigation, respectively. The SAR of growing media was 134% and 110% higher in the fall of 2010 when irrigated by 2 and 3 dS m^{-1}. Statistical analysis showed that the salinity level of irrigation mainly affected the SAR of growing media, while the rate of irrigation did not affect the SAR. Sodium adsorption ratio in the rootzone in summer and spring season increased as the salinity level of irrigation water increased.

Turfgrass growth

Quality of Kentucky bluegrass was higher at the middle of fall and spring seasons (Table 4). The change of color occurs in winter season, as the turfgrass become dormant. Poss et al., (2010) reported that there was no visual deterioration of color of Kentucky bluegrass up to 16 dSm^{-1} of soil salinity

Table 4. Visual quality and clipping dry weight of Kentucky bluegrass at sand based growing media over the reclaimed saline soil irrigated by various salinity levels and irrigation rates.

Irrigation treatments		Year 2009		Year 2010		
Salinity level (dSm^{-1})	Irrigation rate (% ET)	Summer	Fall	Spring	Summer	Fall^{z}
				Visual quality (0-9)^{x}		
0.0	70	7.38 ab	7.61 c	7.96 bc	8.13 a	7.75 ab^{y}
	100	7.26 b	7.75 bc	8.05 bc	8.17 a	7.77 a
	130	7.94 a	8.03 ab	8.33 a	8.23 a	7.95 a
2.0	70	7.19 b	7.76 bc	7.98 bc	7.98 a	7.32 abc
	100	7.28 b	7.83 abc	8.01 bc	8.10 a	7.88 a
	130	7.38 ab	7.90 abc	8.04 bc	8.13 a	7.50 ab
3.0	70	7.19 b	7.79 abc	8.01 bc	7.81 a	6.75 bc
	100	7.47 ab	7.88 abc	7.90 c	7.81 a	6.48 c
	130	7.72 ab	8.15 a	8.19 ab	7.90 a	6.36 c
				ANOVA		
Salinity level		ns	ns	ns	*	**
Irrigation rate		ns	*	*	ns	ns
Salinity vs rate		ns	ns	ns	ns	ns
				Clipping dry weight (g·m^{-2})		
0.0	70	15.07 a	6.46 bcd	9.38 d	17.67 b	12.61 a^{y}
	100	14.14 a	6.19 cd	9.46 cd	18.43 ab	10.75 ab
	130	15.97 a	7.88 a	10.57 abc	18.67 ab	13.00 a
2.0	70	15.53 a	6.95 abcd	10.08bcd	18.19 ab	10.46 ab
	100	15.47 a	7.04 abcd	10.35bcd	18.29 ab	12.20 a
	130	15.75 a	7.52 ab	10.90 ab	18.74 ab	11.38 ab
3.0	70	13.81 a	5.98 d	10.87 ab	17.76 ab	7.76b c
	100	15.54 a	6.79 abcd	10.91 ab	18.71 ab	6.57 c
	130	16.08 a	7.41 abc	11.60 a	19.27 a	7.76 bc
				ANOVA		
Salinity level		ns	ns	**	ns	**
Irrigation rate		ns	**	*	ns	ns
Salinity vs rate		ns	ns	ns	ns	ns

*,** Statistical significance at the errors of 5% and 1% by ANOVA.
^{z} Observed at the end of every seasons.
^{y} Means within a column followed by the same letter are not significantly different based on LSD (error=5%).
^{x} Visual quality of 0=dead grass while 9= optimum quality.

when grown in sand media. Irrigation of non saline water with 130% rate resulted in better quality than 70% of ET rate. Irrigation using by 2 dSm^{-1} saline water did not show difference in visual quality by different rates of irrigation in the first year of experiment. When the 3 dSm^{-1} water was used as irrigation, the 130% irrigation rate resulted in higher quality than 70% of ET rate in the first year. The effect of raising rate of irrigation on the Kentucky bluegrass quality was higher in dry period of fall and spring season, than in wet period of summer season. Salinity affected the visual quality of Kentucky bluegrass mainly in the summer and the fall of 2010. At the end of summer 2010, irrigation using 3 dSm^{-1} saline water reduced the visual quality of Kentucky bluegrass up to below 6, but 2 dSm^{-1} saline water did not decrease the visual quality. In the summer of 2010, irrigation with non saline water resulted in higher visual quality than 2 dSm^{-1} and 3 dSm^{-1} saline water. Compared to non saline water, irrigation using 2 dSm^{-1} and 3 dSm^{-1} saline water resulted in visual quality decline by 1.3% and 4.16% in summer and by 3.2% and 16.5% in fall, respectively. Pessarakli et al. (2004) reported that salinity of irrigation decrease green turf canopy. Longer water stay at root zone when irrigated by 3 dSm^{-1} saline water may have caused the decline of Kentucky bluegrass quality.

Clipping dry weight of Kentucky bluegrass was high in summer and early fall season and middle of spring season. Irrigation rate of 130% resulted in high clipping dry weight. Irrigation using 3 dSm^{-1} saline water decreased clipping yield of Kentucky bluegrass in fall, but did not decrease the clipping yield in spring. Irrigation rate of 70% with saline water decreased the clipping dry weight of Kentucky bluegrass in fall season. These results suggest that the effect of high salinity level and low irritation rate on Kentucky bluegrass growth is more detrimental in fall than in spring season. Gulzar et al. (2003) reported that increase of NaCl salinity decrease fresh and dry weight of turfgrass. Salinity also decreased the relative and absolute biomass accumulation of Kentucky bluegrass (Gratan et al., 2004). Average clipping dry weight was higher in the summer of 2009 and 2010 than in the fall of 2009 and the spring of 2010. The

Table 5. Root length and dry weight of Kentucky bluegrass at sand base growing media irrigated by various salinity level and irrigation rate over the reclaimed saline soil.

Irrigation treatments		Year 2009			Year 2010		
Salinity level	Irrigation rate	Spring	Summer	Fall	Spring	Summer	Fall[z]
dSm^{-1}	% ET	Root length (cm)					
0.0	70	7.38 a	6.00 b	13.13 bc	18.50 bc	19.0 ab	38.0 bcd[y]
	100	6.18 a	7.50 b	14.63 ab	22.25 ab	19.0 ab	39.8 abcd
	130	6.80 a	10.63 a	11.50 c	17.00 c	20.0 ab	42.8 ab
2.0	70	6.93 a	8.08 b	14.50 ab	21.75 ab	21.0 a	39.8 abcd
	100	8.58 a	8.13 b	15.50 ab	19.00 bc	18.0 ab	35.8 d
	130	6.75 a	7.50 b	13.25 bc	23.50 a	18.0 ab	41.0 abc
3.0	70	8.25 a	8.00 b	13.50 bc	22.50 ab	15.3 b	43.3 a
	100	7.05 a	6.00 b	14.13 abc	23.25 a	19.5 ab	36.5 cd
	130	8.50 a	7.50 b	16.50 a	20.75abc	19.0 ab	27.8 e
ANOVA							
Salinity level		ns	ns	ns	*	ns	*
Irrigation rate		ns	ns	ns	ns	ns	*
Salinity vs rate		ns	**	*	*	ns	**
		Root dry weight (g/ 100 cm^2)					
0.0	70	7.38 a	6.00 b	13.13 bc	18.50 bc	19.0 ab	38.0 bcd[y]
	100	6.18 a	7.50 b	14.63 ab	22.25 ab	19.0 ab	39.8 abcd
	130	6.80 a	10.63 a	11.50 c	17.00 c	20.0 ab	42.8 ab
2.0	70	6.93 a	8.08 b	14.50 ab	21.75 ab	21.0 a	39.8 abcd
	100	8.58 a	8.13 b	15.50 ab	19.00 bc	18.0 ab	35.8 d
	130	6.75 a	7.50 b	13.25 bc	23.50 a	18.0 ab	41.0 abc
3.0	70	8.25 a	8.00 b	13.50 bc	22.50 ab	15.3 b	43.3 a
	100	7.05 a	6.00 b	14.13 abc	23.25 a	19.5 ab	36.5 cd
	130	8.50 a	7.50 b	16.50 a	20.75abc	19.0 ab	27.8 e
ANOVA							
Salinity level		ns	ns	ns	*	ns	*
Irrigation rate		ns	ns	ns	ns	ns	*
Salinity vs rate		ns	**	*	*	ns	**

*,** Statistical significance at the errors of 5% and 1% by ANOVA.

[z] Observed at the end of every seasons.

[y] Means within a column followed by the same letter are not significantly different based on LSD (error=5%).

lowest clipping yield was observed in fall season. Irrigation using 2 dSm^{-1} and 3 dSm^{-1} saline water decreased clipping dry weight by 6.4% and 39.28% in the fall of 2010, respectively when compared to non saline irrigation. Statistical analysis showed that irrigation rate had significant effect on the growth of Kentucky bluegrass in spring and fall season, while salinity level effected clipping dry weight in spring season. In the summer and the fall of 2010, irrigation using 3 dSm^{-1} saline water decreased clipping yield, but using 2 dSm^{-1} saline water treatment did not decrease the clipping yield. This result might suggest that irrigation using 3 dSm^{-1} provided problem after 1 year by water logging in the rootzone, resulting in slower growth of Kentucky bluegrass. Poss et al. (2010) reported that cumulative dry and fresh biomass of Kentucky bluegrass decreased with the increase of salinity.

Root growth of Kentucky bluegrass was intensive in fall and spring season, while low in summer. Irrigation using non saline and 2 dSm^{-1} water resulted that root length was increased as the irrigation rate increased in the fall of 2010 (Table 5). However, 3 dSm^{-1} of saline water decreased root length as the irrigation rate increased. Irrigation using 2 dSm^{-1} and 3 dSm^{-1} saline water decreased the average root length by about 3.2% and 10.7%, respectively when compared to non saline irrigation. Root length was affected by salinity level, irrigation rate and interaction between salinity level and irrigation rate was significant. Irrigation rate of 70% ET increased root length as salinity level of irrigation increased. However, opposite trend was observed at higher rates of irrigation. In low irrigation rate, increased saline irrigation resulted in longer root. However, irrigation rates of 100% and 130% decreased the root length as salinity increased. This result agreed with Nabati et al. (1994) that increased salinity of growing media usually decrease rooting.

Root dry mass of Kentucky bluegrass was increased intensively in fall and spring season, however decreased in summer season. Salinity level of irrigation affected root dry mass of Kentucky bluegrass in fall and spring season. Irrigation rate had relatively lower effect to the root dry mass than salinity level. Irrigation with 3 dSm^{-1} saline water resulted in higher root dry mass in summer, while resulted in lower root dry mass in fall season. In the fall of 2010, irrigation rate of 70% with 2 and 3 dSm^{-1} saline water decreased root dry mass by 5.5% and 5.0%, respectively compared to non saline water with same rate. Irrigation rates of 130% with 2 and 3 dSm^{-1} decreased root dry mass by 14.1% and 42.7% respectively, compared to non saline water. Hillel (1990) reported that attention of optimum irrigation have to be devoted due to application of too much water can be harmful as the application of too little. Irrigation with 3 dSm^{-1} water decreased the root dry mass of Kentucky bluegrass as irrigation rate increased. Huang (2008) reported that deep rooting is a critical factor for turfgrass to maintain cellular hydration by avoiding water deficit. Jordan et al. (2003) reported that reduced irrigation frequency of turfgrass produce a larger and deeper root system.

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염해지 토양을 기반으로 조성된 모래 지반구조에서 관수용수의 량 및 염농도에 따른 토양내 염류 집적과 켄터키 블루그래스의 생육에 미치는 영향

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요　약: 본 연구는 염해지 토양을 기반으로 조성된 모래 지반구조에서 켄터키 블루그래스의 염해 경감을 위한 관수량 및 관수용수의 염 수준 설정에 관한 정보를 얻고자 수행되었다. 시험에 사용된 용기는 바닥에 10 cm 높이로 간척지 논토양을 설치 하였으며, 그 위에 20 cm 높이로 염류 차단을 위해 왕사를 설치하였다. 상토는 20 cm 높이로 세사를 설치 하였으며, 세사에 유기물이 부피비로 5%가 되도록 혼합하여 조성하였다. 상기 용기들은 전기전도도(ECw)가 3-5 dSm^{-1} 수준인 물에 5 cm 깊이로 침지 처리하였다. 조성된 용기에 켄터키 블루그래스 뗏장을 식재하였다. 관수용수의 염처리는 전기전도도가 각각 0 , 2 and 3 dSm^{-1}의 농도로 수행되었다. 관수량은 켄터키 블루그래스의 일 증발산량 대비 70% (3.8 mm day^{-1}), 100% (5.7 mm day^{-1}), 그리고 130% (7.6 mm day^{-1})의 3처리로 하였다. 관수는 3일 간격으로 수행하였다. 상토내 염류의 축적은 관수용수와 모세관 현상에 따른 염 집적이 원인이 되었다. 시험 2차년도 조사시 관수용수의 처리 농도(ECw)가 0, 2, 3 dSm^{-1} 일 때 각 상토의 전기전도도는 (ECe) 3.86 dSm^{-1}, 4.7 dSm^{-1} 그리고 5.1 dSm^{-1} 수준으로 조사 되었으며, SAR은 19.2, 23.9, 27.5로 조사되었다. 관수 량의 경우는 염이 포함된 물을 증발산량의 100%와 130% 살포시는 켄터키 블루그래스 재배 토양내 ECe와 SAR 경감 효과는 없었다. 그러나 실험 1년 차의 경우 관수량이 증가할수록 켄터키 블루그래스의 생육량은 증가 되었다. 2년차 조사에서는 켄터키 블루그래스의 생육이 염농도에 영향을 받는 것으로 조사되었다. 수돗물에 (0 dS m^{-1}) 비해 전기전도도가 2와 3 dS m^{-1} 인 물을 관수시 가시적 품질이 각각 3.2%, 16.5% 감소하는 결과를 보였으며, 예지물의 건물중은 각각 6.4%, 39.3%가 감소하는 결과를 보였다. 또한 뿌리 건물중은 각각 5.5%, 5.0% 감소하는 결과를 보였다.

주요어: 전기전도도, 증발산량, 관수량, 켄터키 블루그래스, 염도, 염