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Effects of Interruption Layer for Capillary Rise on Salt Accumulation and Kentucky Bluegrass *Poa pratensis* Growth in Sand Growing Media over the Reclaimed Saline Soil

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ABSTRACT. This research was conducted to determine the effect of interruption layer for capillary rise on the sand based growing media when growing Kentucky bluegrass (*Poa pratensis* L.) on soil reclamation and saline water irrigation. Growing media profile consists of three layers as top soil of 30 cm, 20 cm of the interruption layer for capillary rise and 10 cm of reclaimed paddy soil. Growing media profile was packed in 30 cm diameter column pots. The top soil was a mixture of sand dredged up from Lake Bhunam Tae Ahn, Korea and peat at the ratio of 95:5 by volume. Bottom part of column was covered with plastic net and the pots were soaked into 5 cm depth saline water reservoir with salinity 3-5 dS m^{-1}. Kentucky bluegrass was established by sod and irrigated using 2 dS m^{-1} saline water (5.7 mm day^{-1}) in 3 days interval. The results showed 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 growing media using gravel as the interruption layer for capillary rise material. The interruption layer for capillary rise of gravel and coarse sand reduced the accumulation of Na by 16% and 25%, ECe by 7% and 13% in the growing media. Visual quality of Kentucky bluegrass was higher in growing media with the interruption layer for capillary rise of gravel than no interruption layer by 8.3 compared to 7.9 in rates. The interruption layer for capillary rise of gravel and coarse sand enhanced the visual quality by 4.1 and 4.0%, root length by 50 and 38%, and root dry weight by 35 and 17% of Kentucky bluegrass, and reduced the accumulation of Na by 16% and 25%, ECe by 7% and 13% in the growing media.

***Key words*: Interruption layer, Kentucky bluegrass, Reclaimed soil, Saline irrigation**

Introduction

Rapid urban population growth pressed land and fresh water usage, thus golf course development often pushed to non arable land such as reclaimed land. Reclaimed soil of Korea belongs to the fluvio marine deposit tidal mud, with soil characteristics of imperfectly drainage, alluvial and saline soil and salic horizon in all of soil depth (Sonn et.al 2005). Salic horizon has salt accumulation horizon and ECe of 30 dS m^{-1} or more (Soil Survey Staff, 1999). Reclaimed soil in Korea has shallow saline water table. Shallow saline water table can cause problems to the turfgrass growth by accumulating salts in golf course area. Many older golf courses used native soil for greens. The greens are more susceptable to damage due to salt and sodium accumulation and the difficulty of leaching these components from the soil growing media (Gross, 2008). Beard (1982) reported that desirable fairway characteristics are not very different from those of putting green. Fairway condition influences aesthetics of the golf course as well as playability. Therefore using reclaimed soil for growing media of Kentucky bluegrass as fairways may has many potential problems, thus sand layer over the reclaimed soil is necessary as growing media.

Sandy soil with shallow saline water table has a potential problem of salt accumulation by capillary rise. Salt moving up from water table to the surface of soil in dry season was driven by evapotranspiration. This condition caused precipitation of calcium and sodium saturated humus and clays of soil, which the sodium will be transported during the following wet period (Duchaufour, 1982). When the water table is shallower and the distance is short of the growing media, the capillary rise will increase (Jorenush and Sepaskhah, 2003). Changes in soil water content generally paralleled changes in EC of soil water, and increases from 4 to 7.5% in soil water content for each 1 dS m^{-1} increase in EC of saline water (Thompson et al., 2007).

Turfgrass irrigation with fresh water is typically considered as low priority use (Kjelgren et al., 2000; Marcum, 2006). Water containing salt (480 ppm) or ECw

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(0.75 dS m^{-1}) can cause salt accumulation, physiological drought, element toxicity, nutrient imbalance, and sodium permeability hazard (Miyamoto et al., 2005), and it may result in high soil ECe over time (Carrow and Duncan, 1998). At 2 dS m^{-1} salinity of irrigation water, relative tolerant turfgrass, such as Bermudagrass, growth was retarded on clay loam soil (Miyamoto and Chacon, 2006). Therefore, drainage is essential for dealing with salt and sodium accumulation (Gross, 2008).

Intermediate layer in the green of golf course prevent the downward migration of particle from the growing media into the gravel (USGA green section staff, 1989), and keep moisture in the root zone (Hunt and Baker, 1996). Bigelow et al. (2001) reported that presence of gravel layer at growing media profile significantly reduced soil water retention, with soil water content was lower when placed above 15 cm gravel layer than placed above 10 cm gravel layer. Without gravel layer, water retention of growing media depend on sand sizes, such as medium > mixed > coarse in water retention. In heavy irrigation, growing medias overlying the gravel layer drained more rapidly than those without the layer (Prettyman and McCoy, 1999). Top soil above 20-25 cm gravel retained more water than soil at similar depths in uniform columns, even though evaporation was generally more rapid than top soil without gravel layer (Unger 1971). The amount of water retained in the growing media was affected by the growing media properties and the coarseness of the underlying layer (Taylor et al., 1993). Moisture retention in the growing media layer is a function of the desorption characteristics of the growing media, its depth and the coarseness of the underlying layer. Water retention in 30 cm deep growing media layers was greatest when the growing media was placed directly over the gravel layer but declined when the growing media was placed over sand and gravel, or directly over sand (Taylor et al., 1994).

Kentucky bluegrass is used extensively for lawn, athletic fields and golf courses (Turgeon, 2002), and forms attractive turf when supplied with adequate water (Meyer and Funk, 1989). Carrow and Duncan (1998) reported that Kentucky bluegrass belong to salt-sensitive turfgrass with an average threshold EC of 3 dS m^{-1}, and 50% reduction of growth in ECe 3 dS m^{-1} was reported by Marcum (2006). However variability in salt sensitivity and tolerance among cultivars was reported (Horst and Taylor, 1983). Study on the effect of salinity on Kentucky bluegrass have been conducted (Horst and Taylor, 1983; Butler et al., 1985, and Qian et al., 2001). Salinity levels that caused 25% shoot growth reduction ranged from 2.0 to 7.8 dS m^{-1}, and salinity levels caused 50% growth reduction was 6.2 to 15 dS m^{-1}. Salinity levels caused 25% root growth decrease of Kentucky bluegrass was 2.2 to 2.5 dS m^{-1}, and salinity levels caused 50% root growth decrease was 4.5 to 15.8 dS m^{-1} (Suplick et al., 2002). Increase of salinity caused increase of root/shoot ratio by weight, beside the elongation of root was better in tolerant plant than entire plant, and shoot growth was decreased linearly in all levels of salinity, while root growth was increased to a maximum point and then declined (Harivandi et al., 1992).

This study was carried out to examine the function of the interruption layer for capillary rise and to compare gravel and coarse sand as interruption layer over the reclaimed paddy soil in sand base growing media for the growth of Kentucky bluegrass under saline condition.

Materials and Methods

Material

Dredged up sand from Bhunam lake in Korea was used for the top soil of growing media growing media. Top soil texture was coarser than USGA recommendation for putting

Table 1. Physical characteristics of reclaimed paddy soil (RPS) and dredged up sand (DS).

Soil sample	Sand	Silt	Clay	Texture Class	WRFC	WA	TP	SHC
		(%)				(%)		(mm h^{-1})
RPS	63.8	32.0	4.9	Sandy loam	19.8	11.4	26.1	37.5
DS	98.1	1.8	0.2	Sand	11.7	8.0	37.9	435

WRFC=water retention at field capacity; WA=water availability; TP=total porocity; SHC=saturated hydraulic conductivity.

Table 2. Chemical characteristics of reclaimed paddy soil (RPS) and dredged up sand (DS).

Soil sample	pH	ECp	ECe	SAR	OM	$CaCO_3$	CEC
		dS m^{-1}			(%)		(me $100g^{-1}$)
RPS	6.67	0.255	5.10	21.4	1.59	7.52	9.33
DS	6.86	0.056	1.39	8.95	0.24	7.40	1.30

RPS= reclaimed paddy soil; DS=dredged up sand green media. Reclaimed soil as the base of the profile, was collected from the top soil of Seosan B reclaimed area in west part of South Korea. Physical and chemical characteristics of RPD and DS were showed in table 1 and table 2.

Experiment were conducted at Dankook University turfgrass field in Cheonan city South Korea from June 2009 to October 2010. Experimental were arranged by randomized designs with 4 replications. Three types of interruption layer used as sub soil were gravel with average diameter of 12 mm, coarse sand with diameter > 2 mm, and without interruption layer treatment. The types of soil profile were 1) growing media with gravel interruption layer (RGL), 2) growing media with coarse sand interruption layer (RCSL), and 3) growing media with no interruption layer (RNL). Growing media profiles were packed in column. Column was made by cutting pipe with 30 cm in diameter and 40 and 60 cm in height, and attached the plastic net at the bottom and soaked into the saline water. Growing media profile consisted of 10 cm reclaimed soil in the bottom, 20 cm interruption layer and 30 cm top soil. Columns were soaked in 5 cm depth reservoir of saline water as saline water table. Water level and salinity were maintained as needed. Kentucky bluegrass in mixture of cultivars of ‘midnight’, ‘unique’ and ‘challenger’ was used. Turfgrass was irrigated by fresh water during the 1st month, and then by saline water of 2.0 dS m^{-1} with 1000 ml every 3 days (5.7 mm day^{-1}). Salinity level was kept in ECw of 3 to 5 dS m^{-1} by adding saline water to increase salinity when the base water salinity was decreased by rain. The saline water brought from the sea of Seosan city and diluted with tab water to 2.0 dS m^{-1} as irrigation source and 3 to 5 dS m^{-1} as base water. Irrigation water has SAR of 6.3, Ca, Mg and Na content of 52.1, 86.3 and 231 ppm, respectively. Complete fertilizer (11-5-7) was applied 3 times per year, with 4 g of N/m^2 per each application. Fertilizer was applied at the initial establishment of sod, and then was applied in 2 months interval. Insecticide and fungicide were applied when the turfgrass showed early symptoms of insect threat or disease. Experimental area had dry period from April to June and September to October, 2009, and from April to June and October to November, 2010. Wet period of Cheonan was July to August 2009 and July to September 2010, respectively (Fig 1).

Turfgrass visual quality, clipping fresh and dry weight, clipping water content, organic content, root length, and root dry weight were investigated. Chemical characteristics of soil pH, ECe, Ca, Mg, Na and SAR were also investigated. Moisture content measured every 1 day, 2 days and 3 days after irrigation using Time Domain Reflectometry (TDR) machine. Turf quality was rated on a 0 – to – 9 scale, where 0 =brown, death turf; 6 = acceptable quality for home lawn; and 9 = optimum color, density and uniformity (Turgeon, 2002). Turfgrass was mowed every week and the clipping was collected using modified scissors basket. Clipping dry weight was measured after drying clipping in a dry oven (model; DNC-122sp) at 100°C for 24 hour. Turfgrass visual quality was observed every week by considering color, uniformity, density and ground covering. Root length and root dry weight was measured at the every end of season,

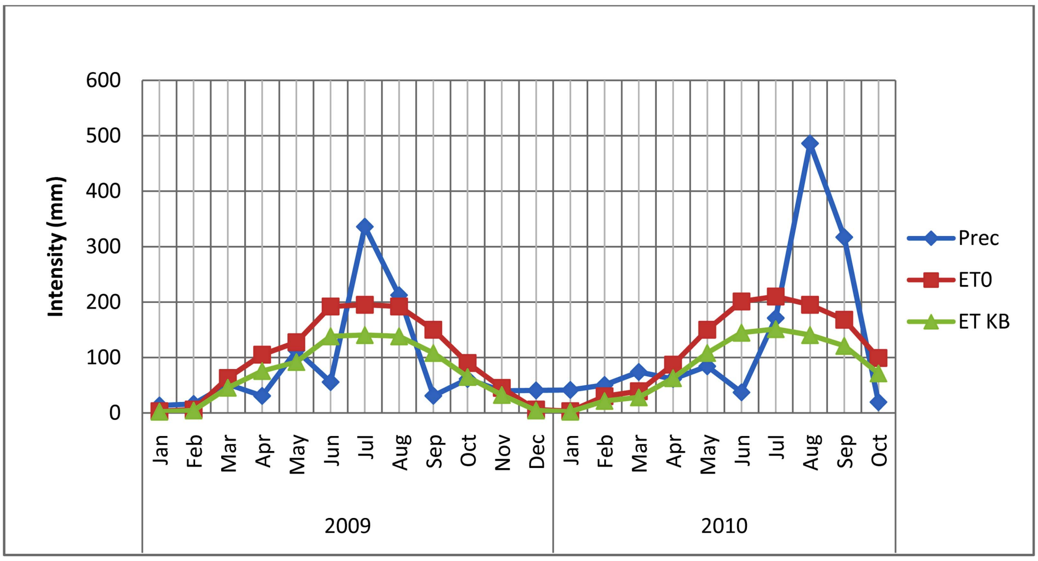

Fig. 1. Monthly precipitation (Prec), potential evapotranspiration (ETo) and evapotranspiration of Kentucky bluegrass (ET KB) in Cheonan. Source of data: www. kma.go.kr. ETo obtained use Blaney and Criddle Method (1952), Sys et al, (1991); ET of Kentucky bluegrass use crop coefficient of cool season grasses in golf course (Brown, 1987).

Table 3. Soil moisture content of sand growing media with 3 types of the interruption layer for capillary rise under saline condition.

Interruption layer	Soil moisture content (%)														
	Summer 2009			Fall 2009			Spring 2010			Summer 2010			Fall 2010		
	1d [y]	2d	3d	1d	2d	3d	1d	2d	3d	1d	2d	3d	1d	2d	3d
RGL	7.5a[z]	5.3b	5.0b	6.1b	5.5b	5.6b	8.3b	8.0b	6.2b	6.6b	5.3b	5.6b	6.5b	6.3b	5.9b
RCSL	7.9a	5.6ab	5.6b	5.9b	6.0b	5.7b	8.6b	8.0b	6.4b	5.9b	4.5b	5.3b	6.0b	5.7b	5.5b
RNL	10.4a	8.0a	7.3a	8.1a	8.7a	8.8a	11.8a	11.4a	9.1a	10.6a	9.0a	9.8a	8.7a	8.5a	8.7a

RGL= growing media with gravel as interruption layer; RCSL= growing media with coarse sand as interruption layer; RNL= growing media with no interruption layer.
[z] Means within a column followed by the same letter are not significantly different based on LSD.
[y] d= day after irrigation.

using soil sampler. Root dry weight obtained from bottom part of the boring samples was washed and the lower part below the thatch layer was cut and dried in a oven at 100°C for 24 hours.

Soil pH was measured using pH meter (pH-220L) with ratio soil : water of (1:5). Electrical conductivity (ECp) was measured by conductivity meter (cond 720). ECe was calculated using texture class conversion factor from ECp data (Carrow and Duncan, 1998). Calcium (Ca) and Magnesium (Mg) were analyzed by 2 steps. First step was to remove the Ca and Mg from soil complex. Ten grams of dry soil were mixed with 30 ml of ammonium acetate (1 M pH 7) in flask and were shacked at 180 rpm for 30 minutes, then were filtered and leached by 70 ml of ammonium acetate to get extract solution in ratio 10:1 of ammonium acetate and soil (Tan, 1995). Total hardness (Ca + Mg) was 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. Calcium was analyzed by using 2 ml solution extract buffered by 2 ml NaOH (2 M), colored by calcon indicator and then titrated by EDTA 0.01 M solution. Mg in ppm was calculated by substracting the Ca in ppm from total hardness (Hach, 1996; Austin, 2005). Sodium concentration was calculated by soil conductivity (ECe) data in dS m^{-1} multiplied by 10 and then be subtracted by Ca and Mg content (Hach, 1996). Data was analyzed by SAS to provide statistical significance.

Results and Discussion

Salt accumulation

Soil moisture contents of the treatment without interruption layer were consistently higher than the treatments with interruption layer. Soil moisture content of RGL was not different from RCSL (Table 3). This may indicate that drainage capability is low or continuous capillary rise of water from reservoir in the soil profile was continued when the interruption layer is absent, which may result in the accumulation of salts in growing media layer from shallow saline water table. Moisture content after irrigation to the soil underlain by sand or gravel was reported to change very little compare to uniform soil (Miller and Bunger, 1963). In this study, lost of water in growing media was affected by the introduction of interruption layer, suggesting that water may be moved up from the shallow water reservoir when there was no interruption layer. Lower moisture content of RCSL at 1 and 2 days after irrigation than RGL at summer 2010, may be related to the size of interruption layer particle. Effect of a coarse layer on increasing water retention in the soil above depends on the difference in particle size between the layers and the sharpness of the boundary between the layer (Miller, 1969). Unger (1971) reported that top soil above 20-25 cm of gravel retained more water than the soil of similar depths with uniform soil columns. Ripple et al. (1972) reported that evaporation from bare and layered soil with a high water table was affected by water table depth, air temperature, air humidity, and wind velocity.

Accumulation of Na was maximal at the end of spring of 2010. Excessive rain in summer resulted in the decreased salt content (Table 4). The interruption layer for capillary rise reduced the Na accumulation in the growing media. Interruption layer of gravel reduced the Na content in average by 25.2% while interruption layer of coarse sand reduced Na content by 17.3% from spring to fall of 2010 (Table 4). In the summer of 2009, the RNL showed Ca lower than RGL and RCSL, but higher than RCSL but same with RGL. ECe, SAR and Na content. At fall of 2009, there was significant difference on soil pH. In spring of 2010, the RNL showed lower Mg, higher ECe, higher SAR and Na content compared to RGL. The RNL also showed Na, ECe and SAR higher than RCSL. There no difference of salt accumulation was observed between RGL and RCSL. This result suggested that interruption layer reduced Na, ECe and SAR accumulation, while held Ca and Mg. Calcium content

Table 4. Calcium, magnesium and sodium contents of sand growing media with 3 types of the interruption layer for capillary rise under saline condition.

Interruption layer	Year 2009		Year 2010		
	Summer	Fall	Spring	Summer	Fall [y]
	Ca (ppm)				
RGL	139.4 a [z]	103.3 a	89.2 a	101.8 ab	130.3a
RCSL	134.4 a	89.7 a	99.7 a	116.8 a	126.3a
RNL	105.3 b	99.3 a	78.2 a	87.7 b	111.3a
	Mg (ppm)				
RGL	66.0 a	31.6 a	64.5 a	79.7 a	159.6a
RCSL	47.7 a	41.4 a	61.1 ab	59.9 a	172.7a
RNL	68.4 a	43.2 a	45.3 b	62.3 a	175.8a
	Na (ppm)				
RGL	471.6 a	388.9 a	888.2 b	133.4 b	162.5a
RCSL	326.3 b	348.0 a	922.3 b	171.9 ab	119.6a
RNL	526.2 a	347.2 a	1064.0 a	241.1 a	189.9a

RGL= growing media with gravel as interruption layer; RCSL= growing media with coarse sand as interruption layer; RNL= growing media with no interruption layer.
[y] Observed at the end of every seasons.
[z] Means within a column followed by the same letter are not significantly different based on LSD.

growing media decreased until the spring of 2010, but increased in the summer of 2010, and this trend was similar in Mg. Sodium content was higher in the spring, but frequent summer rains washed Na in soil resulting in a significantly lower Na in fall. After one year of experiment the ECe, SAR and Na content increased more than 100%. Salt accumulation in RNL was believed to be by water movement from the base saline water table, as well as by saline irrigation.

Electric conductivity (ECe) of growing media increased significantly in the spring of 2010, which indicates the accumulation of salts. However, frequent rainfall decreased ECe during the summer of 2010. In the fall of 2010, ECe of growing media increased back again. This result agreed with Huck et al. (2000) that increasing salt accumulation typically occur in late summer and early fall. Salts were accumulated fast until June of 2010 when the ET of Kentucky bluegrass about 140 mm and precipitation was only about 40 mm (Fig. 1). At this time, ECe of RGL, RCSL and RNL growing media were 4.8, 5.0, and 5.4 dS m^{-1} and SAR were 24.8, 25.5, and 34.0, respectively. Tyagi (2003) reported that an upward moisture flux due to high evaporative demand in summer, commonly results in salinity build up. However, there were frequent rainfalls in July and August of 2010 in Cheonan, and salts were washed out during summer by 63.5, 63.4 and 62.8% in ECe of RGL, RCSL and RNL respectively. The salt accumulation of RNL was higher than RGL and RCSL under the same irrigation condition. This study agreed to the report of cumulative capillary rise affecting the total increase of salt content in soil profile (Jorenush and Sepaskhah, 2003). This result suggested that the interruption layer for capillary rise prevented salt accumulation. Interruption layer of gravel reduced the average ECe and SAR by 7% and 23% while interruption layer of coarse sand reduced the average ECe and SAR by 13% and 32%. The lower salt accumulation affected by interruption layer may be related to the soil moisture content. This result agreed with Bigelow et al. (2001) that the gravel layer as an interruption layer reduced growing media water retention at top soil. In heavy irrigation, growing media overlying the gravel layer drained more rapidly than overlaying the sand (Prettyman and McCoy, 1999). On the other hand, RNL showed higher moisture content than RGL and RCSL, because shorter distance from water table. When the water table is shallower and the distance is short of the growing media, the capillary rise will increase (Huck et al., 2000).

Soil pH increased from summer to fall season of 2009, and then followed by decrease of soil pH until summer of 2010. Increased salinity from fall season to spring paralleled with decrease of pH. Wilhelm et al., (2010) reported that the soil pH was low in the second year of experiment even though the salinity was high when irrigated by saline water, while Kütük et al. (2004) reported that electrical conductivity of the root-zone increased due to increasing salinity and time,

Table 5. The pH, electric conductivity (ECe) and sodium adsorption ratio (SAR) of sand growing media with 3 types of the interruption layer for capillary rise under saline condition.

Interruption layer	Year 2009		Year 2010		
	Summer	Fall	Spring	Summer	Fall y
			pH		
RGL	6.47 a z	6.91 a	6.71 a	6.25 b	6.57 c
RCSL	6.50 a	6.79 a	6.58 b	6.41 a	6.82 b
RNL	6.30 b	6.62 b	6.61 b	6.54 a	7.06 a
			ECe (dSm-1)		
RGL	3.3 a	2.5 a	4.8 b	1.75 a*	2.69 a
RCSL	2.5 b	2.3 a	5.0 b	1.83 a	2.59 a
RNL	3.4 a	2.4 a	5.4 a	2.01 a	2.85 a
			SAR		
RGL	11.9 ab	12.4 a	24.8 b	3.49 b	3.21 a
RCSL	8.9 b	10.8 a	25.5 b	4.62 ab	2.29 a
RNL	13.8 a	10.6 a	34.0 a	6.75 a	3.68 a

RGL= growing media with gravel as interruption layer; RCSL= growing media with coarse sand as interruption layer; RNL= growing media with no interruption layer.
z Means within a column followed by the same letter are not significantly different based on LSD.
y Observed at the end of every seasons.

whereas pH decreased. Decrease of pH may be caused by SO_4 from saline water table, since sea water mainly contain salt NaCl, $MgCl_2$ and Na_2SO_4 (Ravisankar et al., 1988).

Kentucky bluegrass growth

Visual quality of Kentucky bluegrass was high at the end of July, the end of fall October and the end of spring season (Fig. 2). In summer of 2010, turfgrass quality of RNL was significantly lower than RGL and RCSL. The lower visual quality trend of RNL than RGL was observed to fall of 2010 (Table 6). In the spring of 2010, there was no difference in quality of Kentucky bluegrass among treatments. Kentucky bluegrass showed similar visual quality from the initiation of this experiment to end of second year when the interruption layer was introduced. Interruption layer of gravel increased the average visual quality by 4.1% while

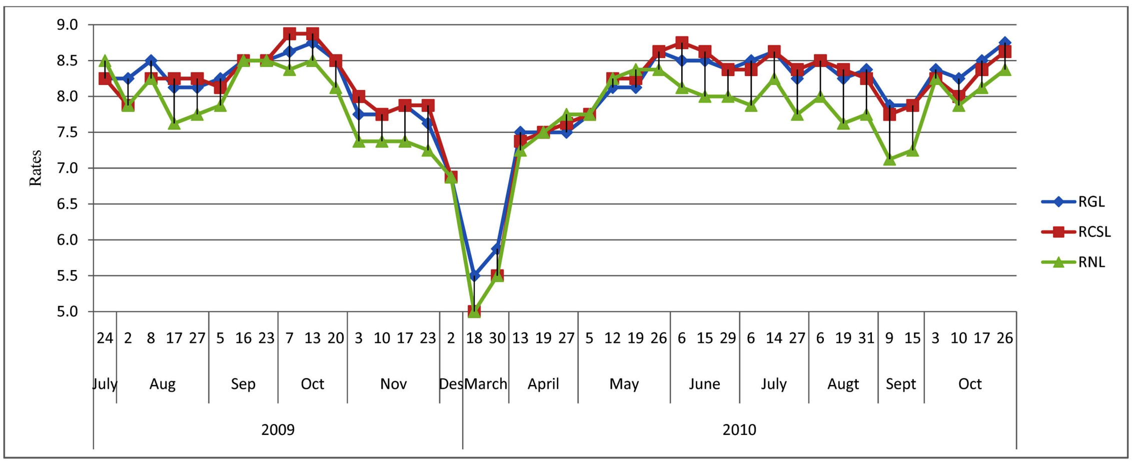

Fig. 2. Visual quality of Kentucky bluegrass at sand growing media with 3 types of the interruption layer for capillary rise under saline condition. RGL = Growing media with gravel layer; RCSL = Growing media with coarse sand layer; RNL= Growing media without sub layer.

Table 6. Kentucky bluegrass growth with various the interruption layer for capillary rise of growing media in saline condition.

Interruption layer	Year 2009		Year 2010		
	Spring	Fall	Spring	Summer	Fall
	Visual quality (rates 1- 9) ^{y}				
RGL	8.3 a^{z}	8.2 a	8.1 a	8.4 a	8.3 a
RCSL	8.2 a	8.3 a	8.1 a	8.4 a	8.1 ab
RNL	8.0 a	7.9 b	7.9 a	7.9 b	7.8 b
	Clipping dry weight (g m^{-2}) ^{y}				
RGL	13.84 b	6.04 ab	10.71 ab	19.09 a	10.49 a
RCSL	12.35 b	5.72 b	10.06 b	17.17 b	10.16 a
RNL	17.45 a	6.62 a	11.77 a	18.93 a	9.43 a
	Clipping fresh weight (g m^{-2}) ^{y}				
RGL	-	22.29 b	34.79 ab	61.63 a	30.55 a
RCSL	-	20.39 b	31.86 b	54.34 b	29.17 a
RNL	-	28.73 a	39.66 a	64.24 a	28.30 a
	Leaf leaf water content (%) ^{y}				
RGL	-	193.0 b	216.3 b	225.2 b	191.5. a
RCSL	-	191.2 b	208.8 b	219.6 b	187.7 a
RNL	-	237.2 a	232.2 a	240.2 a	200.2 a
	Root length (cm) ^{x}				
RGL	10.0 a	16.1 a	19.3 a	21.3 a	34.5 a
RCSL	9.6 a	12.1 b	19.0 a	20.0 a	31.8 a
RNL	7.4 a	9.0 c	14.0 b	13.5 b	23.0 b
	Root dry weight (g 100cm^{-2}) ^{x}				
RGL	1.27 a	1.35 a	3.98 a	3.26 a	4.41 a
RCSL	1.51 a	1.67 a	3.42 ab	3.26 a	3.80 ab
RNL	0.64 a	0.80 a	2.47 b	2.55 b	3.25 b

RGL= growing media with gravel as interruption layer; RCSL= growing media with coarse sand as interruption layer; RNL= growing media with no interruption layer.

^{z} Means within a column followed by the same letter are not significantly different based on LSD.

^{y} Average value from weekly data.

^{x} Root length and dry weight were observed at the end of each season.

coarse sand increased the average visual quality by 4.0% compared to growing media without interruption layer. Poss and Russel (2010) reported that no visual deterioration of color and quality of Kentucky bluegrass was observed up to16 dS m^{-1} soil salinity when grown on sand media.

Clipping dry weight of Kentucky bluegrass in RNL was higher in average than other treatments in the first year of establishment (Table 6). During the excess rainy period of August 2010, clipping yield of RGL was higher than RCSL and RNL (Fig. 3). Kentucky bluegrass was also responsive to the fertilizer application (Fig. 3). Clipping dry weight of RNL was higher than other treatments, while no difference was observed between in RGL and in RCSL. High clipping yield of RNL in first year of establishment may be caused by higher soil moisture content. However, from August 2010, the clipping dry weight in RGL was higher than in RNL. Total dry weight yield of RGL per season was higher than RCSL (Table 3). Clipping fresh weight yield showed similar trend with clipping dry weight yield. Salinity of RCSL was higher than RGL in the spring of 2010. This may caused that the clipping dry weight of Kentucky bluegrass of RCSL was lower than RGL. Salinity was reported to reduce

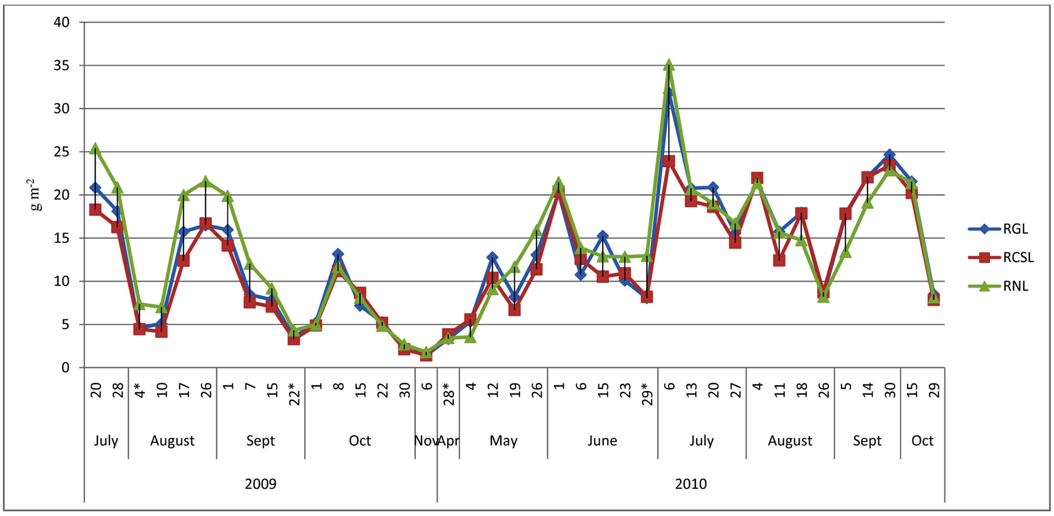

Fig. 3. Clipping dry weight of Kentucky bluegrass at sand growing media with 3 types of the interruption layer for capillary rise under saline condition. RGL = Growing media with gravel layer; RCSL = Growing media with coarse sand layer; RNL= Growing media without sub layer.

the growth of plant (Suplick et al., 2002), yield (Corwin and Lesch, 2003), relative and absolute biomass accumulation of Kentucky bluegrass (Grattan et al, 2004) and cumulative dry and fresh biomass production of Kentucky bluegrass (Poss and Russel, 2010). Kentucky bluegrass growth may depend on climatic and environment condition. Response of plants to salt stress is a function of salt concentration, stage of plant development and other environmental factors (Al-Busaidi et al., 2008). Yoon and Lee, (1992) reported that foliar growth of Kentucky bluegrass in Korea was highest in June and lowest in August. Salinity can directly affect the nutrient uptake by plant, and susceptibility to injury or internal nutrient requirement. Nutrient addition has been successful in improving crop quality than the correction of Na-induced Ca^{2+} deficiencies by supplemental calcium (Grattan and Grieve, 1999). Salt accumulated gradually from early establishment stage to the middle of summer 2010, but reduction of clipping dry weight did not follow the salt accumulation trend. Clipping dry weight of Kentucky bluegrass was higher in wet condition period than in dry condition period. This result agreed with Smets et al. (1997) that in sandy soil the irrigation water quantity has greater impact than the quality of irrigation water.

Leaf water content was significantly different between

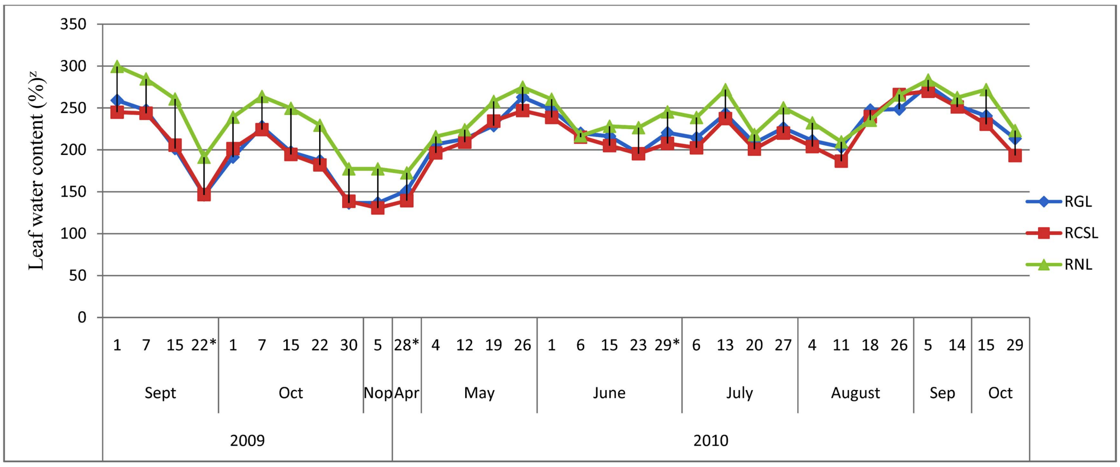

Fig. 4. Leaf water content of Kentucky bluegrass at sand growing media with 3 types of the interruption layer for capillary rise under saline condition. RGL = Growing media with gravel layer; RCSL = Growing media with coarse sand layer; RNL= Growing media without sub layer. *fertlizer application. ^{Z}water content of leaf per dry weight of leaf.

among 3 treatments of growing media. There were significant differences for clipping fresh weight between RGL and RNL in dry period of fall 2009. Leaf water content of RNL was higher than RGL and RCSL, but there was no difference between RGL and RCSL treatment (table 6). At the end of August 2010, when rain intensity was higher, there was no difference in leaf water content among RGL, RCSL and RNL. Higher leaf water content was generally observed in RNL treatment (Fig. 4). Leaf water content commonly relates to the turgidity of turfgrass shoot. In saline sites, plant water absorption was driven by water potential difference between soil and plant root. Since high concentration of solute or salt in soil will increase solute potential, decrease of plant to water absorption is expected (Hilel, 1990). Tissue was accounted by turgidity pressure decline as water supply to the shoot decreased (Lee at al., 2005). Water supply to the shoot may be affected not only by salt concentration, but also by the amount of water available for plant, thus resulting in higher moisture content in saline soil condition resulted in higher leaf water content of Kentucky bluegrass.

Overall, no difference was found for root length between RGL and RCSL (Table 6). Both treatments produced longer root than RNL treatment. Interruption layer of gravel increased average root length and root dry weight by 50% and 35% while interruption layer of coarse sand increased average root length and root dry weight by 38% and 17%.

Root dry weight of RGL was higher than RNL in second year of observations. The RCSL treatments produced root dry weight higher than RNL in summer of 2010, whereas in other seasons there was no difference to RGL or RNL. Capillary rise for interruption layer of gravel increased root dry weight of Kentucky bluegrass significantly. Growth of root may be related to the soil salinity. Even though Nabati et al. (1994) reported that increased salinity of growing media decreased rooting, but this result agreed with Pessarakli et al. (2004) that the shoot dry weight decreased with salinity treatment.

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임해 간척지에서 모래상토 층에 모세관수 차단 층의 도입이 염류 집적과 켄터키블루그래스 생육에 미치는 영향

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요 약: 본 연구는 임해 간척지와 염분의 농도가 높은 관수조건에서 모세관수의 차단층이 염류집적과 켄터키블루그래스의 생육에 미치는 영향을 알아보고자 수행되었다. 생육지반으로는 표토 30 cm, 차단층 20 cm가 10 cm 두께의 간척지 토양위에 조성되었다. 표토로는 태안군 부남 호에서 준설된 모래가 사용되었으며 유기물은 부피비 5%로 혼합되었다. 30 cm직경의 PVC 주름관을 절단하여 지반구조 용기가 제작되었고 바닥은 PVC망사를 이용하여 토양의 이동을 차단하였다. 용기는 5 cm깊이의 저수조에 설치되었으며 저수조에는 3-5 dsm^{-1} 염도의 희석 바닷물이 채워졌다. 켄터키블루그래스는 뗏장을 사용하여 조성되었으며 2 Sm^{-1}로 희석된 바닷물이 관수원으로 사용 되었고 일평균 5.7 mm의 관수가 3일 간격으로 수행되었다. 차단층을 생략한 지반은 봄철에 염분의 집적이 최대를 보여 토양전기전도도가 5.4 dSm^{-1}에 달하였으며 SAR은 34.0을 보였고 차단층설치구의 토양전기전도도 인 4.6 dSm^{-1} 과 SAR 8.24에 비해 현저하게 높은 염의 집적을 보였다. 차단층의 소재별 차이를 볼 때 콩자갈과 조사의 사용 시 토양중 Na농도가 가각 16%와 25% 감소하였고 토양전도도는 7%와 13%감소하였다. 차단층 처리구의 켄터키부루그래스 품질은 평균 가시적 평가 8.3을 보여 차단층을 생략한 처리구의 평균 가시적 평가 7.9 보다 높았다. 콩자갈과 조사 차단층 소재는 차단층을 생략한 경우에 비해 켄터키부루그래스의 가시적 품질을 각각 4.1%, 4.0% 증가 시켰으며, 뿌리의 길이를 50%와 38%, 뿌리의 건중을 35%와 17% 증가 시켰다. 상토층의 Na 함량도 콩자갈과 조사 차단층에 의해 각각 16%와 25% 감소하였으며 토양 전기전도도도 7%와 13% 감소하였다.

주요어: 간척지, 염수관수, 차단층 켄터키블루그래스