Asian J. Turfgrass Sci. 25(2):208~216, 2011
pISSN 1229-3253
Research Articles

Asian Journal of Turfgrass Science
The Turfgrass Society of Korea

Effects of Several Amendment Materials on Salt Accumulation and Kentucky Bluegrass (*Poa pratensis* L.) Growth in Sand Growing Media Established Over the Reclaimed Saline Soil

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ABSTRACT. The purpose of this study was to find soil-amendment materials those support the growth of Kentucky bluegrass and reduce salt accumulation at the sand based growing media in saline conditions. Rootzone profile in columns consisted of 20 cm of top soil, 20 cm coarse sand as capillary rise interruption layer and 10 cm reclaimed paddy soil as the base of the profile. Top soils were mixtures of dredged sand (DS) and amendment with compositions of 90% sand + 10% peat moss (SP), 80% sand + 10% soil + 10% bottom ash (SSoBa), 80% sand + 20% soil (SSo), 90% sand + 5% peat + 5% zeolite (SPZ), and 80% sand + 20% bottom ash (SBa). The top soil mixtures of DS and amendments were treated with and without gypsum (Gp). The columns were soaked into 5 cm depth saline water reservoir with the salinity level of 3-5 dSm^{-1}. Irrigation of 2 dSm^{-1} saline water with rate of 5.7 mm day^{-1} was applied by 3 day interval. Application of zeolite decreased SAR, application of gypsum decreased ECe of the sand amended by peat + zeolite and decreased the SAR of sand amended by bottom ash. The SP and SSoGp resulted in higher clipping dry weight of Kentucky bluegrass. The SSoGp and SPZGp showed longer root lengths. The SP and SBaGp showed higher visual quality. Addition of gypsum to soil and bottom ash treatments resulted in the increased shoot growth, whereas additional gypsum to the treatments of peat, soil and zeolite increased the root growth of Kentucky bluegrass.

Key words: *Kentucky bluegrass, salt accumulation, soil amendment, saline*

Introduction

In saline condition, water and salt balance became the concern in recent studies, since they are sensitive to rooting depth, crop factors, actual soil evaporation and the soil water retention (Smets et al., 1997). Removal of excessive salt not only by carrying the leaching program, but also by performing soil amelioration can improve soil permeability (Qadir et al., 2000). Amelioration to achieved good drainage is also an essential program to deal with salt and sodium accumulation (Gross, 2008). For the effectiveness of the leaching program, soil textural and structural properties, soil water content distribution, and the rate of infiltration should be considered to control the efficiency of downward movement of water and solutes (Lavado et al., 1996). In modern golf courses, sand is a common choice for the turfgrass growing media. Even though sand capping all the golf course area is an expensive choice (Waltz and McCarty, 2000) sand gives many benefits. Inorganic amendments can be chosen if they can increase cation exchange capacity and moisture retention, reduce nutrient leaching potential, regulate root zone temperature, and improve capillary water movement without detrimental effects on rootzone texture, drainage or air exchange (Huang and Petrovic, 1995). Soil also can be used as amendment material for sand based growing media, since rootzone containing soil was essentially equal to the rootzone without soil (Bigelow et al., 1999; Freddie et al, 2003; Gaussion et al., 2006).

The other abundant and cheap amendment material is bottom ash. Bottom ash is a waste of coal in power plant that represents 13 – 20% of the total ash remaining in the bottom of a coal-fired boiler after combustion (Korcak, 1995). Fine bottom ash mixed with soil by 1:1 ratio was successfully used for construction of the Phoenix Links golf course (Buck et al., 2005). Shell et al. (1989) reported that bottom ash has potential as an agronomic soil additive that will not be detrimental to soil, crops, or environment. Bottom ash is high in nutrient values and has been used as a soil amendment (Adriano et al., 1980), without any adverse effects on soil and crop (Sell et al., 1989). Major constituents of bottom ash are Ca, Al, Fe, Mg, K, Si, Na and Ti, where Ca, Fe, Mg, K and Si are essential plant nutrients (Korcak, 1995). Williams et al. (1996) reported that application of bark broiler bottom ash on moderately well drained athletic coastal plain soils did not give the adverse effects of heavy

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Received : Nov. 2, 2011, Revised : Nov. 19, 2011, Accepted : Nov. 25, 2011

metals on soil. Soil amended with heavy proportions of BA is not phytotoxic and supports turfgrass growth (Buck et al., 2005; Lee et al. 2010).

Zeolite has also become a common soil ameliorate in sand based growing media. Zeolite is the hydrated aluminosilicate materials with high cation exchange capacity from 100-230 me/100 g. Zeolite is negatively charged and can be netralized by soil alkali such as Na^+, K^+, Ca^{2+} and Mg^{2+} (Kharisun, 2005). In golf course implementation, Ho-Ok et al. (2003) reported that sand base putting green California –Z system (85% sand and 15% zeolite, v/v) had higher saturated hydraulic conductivity, infiltration rate, bulk density, CEC and plant available nutrient concentrations compared to California system (100% sand). Qian et al. (2001) reported that the amendment of sand with zeolite increased turf quality during the third months at 3.5 and 6.5 dSm^{-1} salinity levels of soil, even though the beneficial effects was diminished after 5 to 6 months. The problem of amending sand with zeolite in sand growing media is that it reduced the leaching of Na^+ and K^+ and increased the leaching of Ca^{2+} and Mg^{2+}.

Peat is the most frequently used organic amendments in golf course construction, because they have benefits in reducing the soil bulk density, improving rootzone aeration, increasing soil moisture retention, and gradual release of water available to plant (Bigelow et al., 1999; Freddie et al., 2003). The preferable amount of peat as turfgrass growing media was reported by Waltz et al. (2003) as 85% sand + 15% peat. McClellan et al. (2007) reported root zone mixture of sand and sphagnum peat by the ratio of 80:20 has similar growing media properties with sand, sphagnum peat and soil by the ratio of 80:15:5. Taylor and Blake (1979) reported that minimum acceptable value of sand was 87% by mass weight in a sand-soil-peat mixture. It gave the same turfgrass growth quality as those with higher percentage of sand, although the mixtures with higher than 90% gave a greater safety margin. Lower sand contents resulted in poor grass yields, less infiltration rates and decreased drainable porosities. Gaussoin (2005) reported that peat addition to sand based growing media of 0.8% by weight was recommended to provide acceptable turfgrass quality.

The common ameliorant in saline soil is the gypsum (CaSO4). Gypsum has a role in improving flocculation, enhancing aggregate stability, increasing infiltration rate (Shainberg et al., 1989) and increasing Ca^{2+} content and replacing Na^+. Gypsum also improved soil condition and soil permeability (Haisheng et al., 2008) and increased field-saturated hydraulic conductivity of the top saline-sodic soil (Ilyas et al., 1993). Size of aggregate in soil profile has correlation to the effectiveness of gypsum amendment in reducing exchangeable Na percentage (Lebron et al., 2006). Effectiveness of gypsum amendments depends on the soil water electrolyte and Ca concentrations resulted from gypsum dissolution, and on the efficiency of the Na–Ca soil exchange process (Amezketa et al., 2005). Addition of gypsum together with other organic agents in saline-sodic soil could strongly increase the ameliorative effectiveness (Haisheng et al., 2008).

Kentucky bluegrass has been used extensively for lawn, athletic fields and golf courses (Turgeon, 2002). Salinity tolerance of Kentucky bluegrass is largely attributable to the maintenance of higher root growth, and more positive turgor (Qian et al., 2001). Alshammary et al. (2004) reported that the growth of Kentucky bluegrass in the mixed media of sand and isolite was reduced by 50% when irrigated by saline water of 4.9 dSm^{-1}, while 50% reduction of root by the salinity of 5.8 dSm^{-1}. Marcum (2006) also reported that the growth of Kentucky bluegrass was reduced by 50% in the soil of 3 dSm^{-1} ECe. Rahayu et al. (2011) also reported that the saline water of 2 and 3 dSm^{-1} resulted in decreased visual quality of Kentucky bluegrass.

The purpose of this study is to find the acceptable materials for sand based growing media amendment. Soil, zeolite, bottom ash and gypsum were compared to peat as substitutional materials for amendment of sand based growing media in saline soil and saline irrigation condition.

Materials and Methods

Dredged-up sand from Bhunam Lake Taean, Korea was used as sand of rootzone media. Reclaimed soil at the base of the rootzoe profile was the top soil of Seosan B reclaimed area in west part of South Korea. Reclaimed paddy soil (RPS) showed pH 6.7, ECe 5.1 dSm^{-1}, SAR 21.4, organic content 1.59%, CEC 9.33 me/100 g and $CaCO_3$ 7.52%. Soil texture of reclaimed paddy soil was sandy loam with sand, silt and clay contents of 63.8%, 32.0%, and 4.9%, respectively. Rootzone profile consisted of top soil of 20 cm, interruption layer with coarse sand > 2 mm of 20 cm and reclaimed paddy soil (RPS) of 10 cm as the bottom layer. The saline water brought from the sea of Seosan city was diluted by tab water to 2.0 dSm^{-1} for irrigation and 3 to 5 dSm^{-1} for base water table. Irrigation water has SAR of 6.3, and Ca, Mg and Na contents of 52.1, 86.3, and 231 ppm, respectively. Columns were soaked into 5 cm depth of reservoir of saline water base as saline water table. Water level and salinity were controlled by addition of water. Salinity level was kept in ECw 3 to 5 dSm^{-1} by adding saline water to increase salinity when the base water salinity was decreased by rain.

Peat, soil, bottom ash, zeolite, and gypsum were used to amend sand based rootzone media. Soil was collected from the average agricultural land in Cheonan, belonging to sandy loam with 0.32% organic matter. Gypsum rate was 58.6 gm^{-2}. Gypsum contained Ca (23.3%) and sulfur (18.6%). Bottom ash was characterized as loamy sand texture, containing

Table 1. Physical and chemical characteristics of growing media used in this experiment.

Growing media[z]	WRFC (%)	Total porosity (%)	SHC (mm/ h)	pH	ECe (dSm^{-1})	Na (ppm)	SAR
S + 5 % P	18.8	41.8	202	6.3	1.0	102.6	3.9
S + 10 %P	20.9	43.4	217	6.6	1.2	142.8	5.5
S+10 % So + 10 % BA	19.2	39.8	50	6.5	3.0	531.1	17.9
S +20 % So	20.7	43.3	50	7.1	1.5	171.9	5.6
S + 5% P +5% Z	16.6	42.2	250	5.9	0.9	25.5	0.8
S + 20% BA	22.0	39.8	90	7.2	1.9	289.5	10.3
S+ Gp	17.2	42.5	208	7.1	-	-	-
So	18.1	40.9	215	7.0	0.7	-	-

[z] BA=bottom ash, S = sand, So = soil, P = peat, Z= zeolite, Gp = gypsum.
WRFC: water retention at field capacity; SHC; saturated hydraulic conductivity

0.88% of organic carbon. Zeolite analysis was SiO_2 61-69%, Al_2O_3 12-15%, Fe_2O_3 18-29 %, MgO 0.99-1.5%, CaO 3-3.4%, Na_2O 1.5-2.2%, K_2O 3-3.5%, and P_2O_5 0.9-1.5%. Top soil consisted of 5 major treatments with amendment material and 2 treatments with gypsum ameliorant as 5×2 factorial combination. The mixtures of top soil were 90% sand + 10% peat moss (SP), 80% sand + 10% soil + 10 % bottom ash (SSoBa), 80% sand + 20% soil (SSo), 90% sand + 5% peat + 5% zeolite (SPZ), and 80% sand + 20% bottom ash (SBa). Then, the mixtures of DS and amendments were treated with and without gypsum application. Chemical and physical characteristics of materials used in this experiment were summarized as Table 1.

Experiment was conducted at Dankook University Turfgrass Field Laboratory in Cheonan, Korea from June 2009 to October 2010. Columns were arranged by completely randomized design with 3 replications. Turfgrass was irrigated by fresh water during first one month, and then was followed by saline irrigation. Salinity levels of irrigation water was ECw of 2.0 dSm^{-1} containing 52.1 ppm of Ca, 86. 3 ppm of Mg, 231 ppm of Na, and SAR of 6.3. Complete fertilizer (11-5-7) was applied 3 times per year, with 4 gNm^{-2} per each application. Fertilizer was applied at the initial establishment of sod, and then was followed by 2 month 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 in 2009, and from April to June and October to November in 2010. Wet period of Cheonan was July to August in 2009 and July to September in 2010, respectively.

Turfgrass was mowed every week and the clipping was collected. Clipping dry weight was measured after drying at 100ºC for 24 hour in dry oven (model; DNC-122sp). Visual quality of turfgrass was evaluated every week by measuring color, uniformity, density and ground coverage (Rahayu et al., 2010). Root length was measured every season, by using soil sampler. Electrical conductivity was measured by conductivity meter (cond 720). ECe was calculated using texture class conversion factor from ECp data (Carrow and Duncan, 1998). Sodium was calculated by soil conductivity (ECe) data in dSm^{-1} multiplied by 10 and then substracted by Ca and Mg content (Hach, 1996). Calcium and magnesium analysis was performed by using 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 shaken at 180 rpm for 30 minutes, then were filtered and leached by 70 ml of ammonium acetate to get extract solution in the 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. Substracting the Ca in ppm from total hardness was the Mg in ppm (Hach, 1996; Austin, 2005). Data were analyzed by SAS to provide statistical significance.

Results and Discussion

Salt accumulation

The most accumulation of Na was observed in the spring of 2010 without significant statistical differences among treatments (Table 2). However, Na accumulation tended to be higher in peat and soil amendment. Application of gypsum increased Na content in soil amendment, but decreased Na content in peat amendment. In dry period, movement of salt is directed towards the surface by capillary rise due to evaporation. The concentration of the solutions increase and the precipitation of calcium salts occur, which

Table 2. Change of sodium content at sand base growing media with various amendment materials under the saline condition.

Growing media[z]	Year 2009		Year 2010		
	Summer	Fall	Spring	Summer	Fall
	(ppm)				
S+P	437.9 ab[y]	465.8 bcd	858.0 a	264.8 a	393.0 ab
S+So+Ba	580.1 a	589.8 ab	655.2 a	138.8 bc	266.6 bc
S+So	372.3 ab	375.9 d	749.2 a	134.7 bc	326.9 bc
S+P+Z	571.4 a	451.2 bcd	726.8 a	112.4 bc	299.8 bc
S+Ba	369.4 ab	372.8 d	678.9 a	169.3 abc	337.8 ab
S+P+Gp	409.6 ab	464.3 bcd	679.8 a	189.6 ab	317.5 bc
S+So+Ba+Gp	515.3 a	637.2 a	738.2 a	71.0 c	266.9 bc
S+So+Gp	483.8 ab	539.3 abc	798.3 a	169.2 abc	476.3 a
S+P+Z+Gp	258.5b	428.0 cd	747.2 a	54.5 c	191.8 c
S+Ba+Gp	374.1 ab	518.4 abc	755.1 a	131.7 bc	218.5 bc

[z] S= sand; P=peat; Ba= bottom ash; So= soil; Z= zeolite; Gp=gypsum.
[y] Means within a column followed by the same letter are not significantly different based on LSD (α=0.05).

allows the saturation of a part of the humus and clays by Na, which can be transported in the following wet period (Duchaufour, 1982). After leaching Na during the summer of 2010, Na content in peat amendment was still higher than the other treatments. Peat can hold water more (Bigelow et al., 1999), hence this hold when occurred in saline water resulted in the hold of sodium. Application of gypsum decreased Na accumulation in peat and peat + gypsum media. Until the summer of 2010, application of gypsum decreased Na content in all of the growing media except the SSoGp. The SSoGp also showed higher Na content in the fall of 2010. This result is similar with Narum et al. (1979) where it is stated that increased rates of gypsum did not affect sodium content of the surface soil, but reduced the ratio of sodium to the other salts.

Electrical conductivity (ECe) of growing media showed a tendency to increase during dry season and decrease during wet season (Table 3). Salt accumulation was observed in the spring and the fall of 2010. This result is parallel to Huck et al. (2000) that increasing salt accumulation typically occurs in late summer and early fall. Higher ET and turfgrass growth of summer may cause higher salt move up from saline water table to the topsoil. The gypsum treatments showed higher ECe values compared to those without gypsum application. At the end of the spring and the fall of 2010, growing media amended by peat and soil showed higher ECe than the other treatments. Longer stay of saline water at SP and SSoGp may have caused soil ECe increase. However, environmental factors played a role in controlling salt accumulation (Miyamoto and Cacon, 2006). Excess rain during the summer of 2010 caused the decrease of ECe.

Table 3. Electrical conductivity (ECe) of sand base growing media with various amendment material under the saline condition.

Growing media[z]	Year 2009		Year 2010		
	Summer	Fall	Spring	Summer	Fall[y]
	dSm^{-1}				
S+P	3.5 ab[x]	2.8 bc	5.6 a	2.1 ab	4.2 ab
S+So+Ba	4.5 a	3.2 ab	4.9 a	1.9 abc	3.9 ab
S+So	3.1 b	2.4 c	5.2 a	2.1 ab	4.3 a
S+P+Z	4.5 a	2.8 bc	5.1 a	1.7 abc	3.9 ab
S+Ba	3.6 ab	2.2 c	4.8 a	1.7 bc	3.8 b
S+P+Gp	3.8 ab	2.6 bc	4.9 a	1.9 abc	4.2 ab
S+So+Ba+Gp	4.3 a	3.5 a	5.2 a	1.8 abc	4.0 ab
S+So+Gp	4.2 a	3.1 ab	5.6 a	2.1 a	4.2 ab
S+P+Z+Gp	3.5 ab	2.8 bc	5.2 a	1.6 c	3.8 b
S+Ba+Gp	3.7 ab	3.0 ab	5.0 a	1.8 abc	3.9 ab

[z] S= sand; P=peat; Ba= bottom ash; So= soil; Z= zeolite; Gp=gypsum.
[y]Observed at the end of every season.
[x]Means within a column followed by the same letter are not significantly different based on LSD (α =0.05).

Application of gypsum resulted in lower ECe than without gypsum in all treatments except SBaGp. Zeolite and bottom ash amendments showed lower ECe in the summer of 2010. This result may be related to the lower water contents in top soil in zeolite and bottom ash amendment in the summer of 2010. Bottom ash can promote infiltration rate due to their

Table 4. Sodium adsorption ratio (SAR) of sand base growing media with various amendment material under the saline condition.

Growing media[z]	Year 2009		Year 2010		
	Summer	Fall	Spring	Summer	Fall[y]
S+P	10.2 ab[x]	14.8 b	17.3 a	7.4 a	6.8 ab
S+So+Ba	11.7 a	20.3 a	12.6 a	3.4 bc	4.4 bc
S+So	8.4 ab	12.4 b	15.0 a	3.0 bc	5.4 bc
S+P+Z	11.2 a	13.9 b	14.5 a	2.8 bc	5.1 bc
S+Ba	7.3 ab	13.5 b	13.6 a	4.8 ab	6.1 ab
S+P+Gp	8.2 ab	16.3 ab	13.5 a	5.1 ab	5.3 bc
S+So+Ba+Gp	10.0 ab	20.4 a	14.4 a	1.6 c	4.4 bc
S+So+Gp	9.6 ab	17.3 ab	15.2 a	4.1 bc	9.5 a
S+P+Z+Gp	4.6 b	12.4 b	14.7 a	1.4 c	3.1 c
S+Ba+Gp	7.3 ab	16.5 ab	15.7 a	3.3 bc	3.5 bc

[z]S= sand; P=peat; Ba= bottom ash; So= soil; Z= zeolite; Gp=gypsum.
[y]Observed at the end of every season.
[x]Means within a column followed by the same letter are not significantly different based on LSD (α =0.05).

Table 5. Visual quality of Kentucky bluegrass in sand base growing media with various amendment material under the saline condition.

Growing media[z]	Year 2009		Year 2010		
	Spring	Fall	Spring	Summer	Fall
	Visual quality (1:bad - 9:very good)				
S+P	7.20 a[y]	7.70 a	8.27 a	8.08 a	7.55 a
S+So+Ba	6.53 ab	7.20 a	7.57 c	7.92 a	7.36 a
S+So	6.47 ab	7.47 a	7.98 abc	7.94 a	7.52 a
S+P+Z	6.80 ab	7.47 a	7.85 abc	8.28 a	7.88 a
S+Ba	6.63 ab	7.22 a	7.62 c	8.06 a	7.83 a
S+P+Gp	6.50 ab	7.45 a	8.22 a	8.22 a	7.50 a
S+So+Ba+Gp	6.65 ab	7.37 a	7.68 bc	7.94 a	7.81 a
S+So+Gp	7.00 a	7.65 a	8.10 ab	8.00 a	7.45 a
S+P+Z+Gp	6.20 b	7.33 a	7.95 abc	8.36 a	8.02 a
S+Ba+Gp	6.73 ab	7.60 a	7.87 abc	8.31 a	8.07 a

[z]S= sand; P=peat; Ba= bottom ash; So= soil; Z= zeolite; Gp=gypsum.
[y]Means within a column followed by the same letter are not significantly different based on LSD (α =0.05).

coarse texture (Buck and LaBuz, 2005), thus may have promoted salt leaching, resulting in lower ECe.

SAR increased from the summer to the fall of 2009, and decreased from the spring to the summer of 2010 (Table 4). In the first year of experiment, SAR was generally higher in the fall season of dry weather. However SAR was significantly decreased by high rainfall during summer. Addition of gypsum generally lowered SAR in most treatments. Supply of Ca from gypsum may be the main reason for lowering SAR. However, amendments of peat + zeolite + gypsum showed lower SAR than the other treatments in the fall season of 2010. During the summer of 2010 when the salt was leached out from rootzone, the SSoBaGp and SPZGp showed lower SAR than the others, and significantly lower than peat amendments.

Turfgrass growth

There was no statistical difference among treatments in Kentucky bluegrass visual quality in the fall season of 2009 and the summer of 2010 (Table 5). Differences in turfgrass quality among treatments were significant in the summer season of 2009 and the spring season of 2010. This result was similar with ECe trend. Growth of Kentucky bluegrass usually decreased with the increase of salinity (Poss and Russel, 2010). Kentucky bluegrass quality may be associated with higher water retention. In the first year of experiment, there was no significant difference in visual quality among all treatments. However, in dry period of 2010, peat and soil additions showed higher turfgrass quality than the other amendments. Peat and soil can retain more water as well as nutrients in dry condition.

Zeolite addition also resulted in higher visual quality. Zeolite addition of 15% by volume to sand based growing media increased saturated hydraulic conductivity and field infiltration rate (Ho-Ok et al., 2003). Bottom ash treatments caused lower quality of Kentucky bluegrass than the other treatments due to the coarseness of particles and low water retention as reported by Buck et al. (2005) where bottom ash drained faster than soil. The SSoGp was the closest in quality rating with SP in dry period. Quality of turfgrass reached the maximum value at the middle of the fall of 2009 and middle of the spring of 2010. In high quality condition of 2009, SSo and SBa was lower in quality than SP. In high quality condition of 2010, SSoBa , SBa and SPZ showed lower qualities than SP, whereas the other growing media did not show significant differences. In the fall of 2009, application of gypsum generally increased the quality of turfgrass, except the SP and SPZ. Application of gypsum slightly increased the quality of turfgrass in dry season of the spring of 2010.

Clipping dry weight of Kentucky bluegrass was generally higher in the summer in saline condition (Table 6). This result might be related to the condition that summer is characterized by a wet condition where rain occurs frequently, whereas spring and fall is characterized by dry condition. In saline condition, high rainfall leaches the salts in the rootzone area and minimizes the salt effect, which

Table 6. Clipping dry weight of Kentucky bluegrass in sand base growing media with various amendment material under the saline condition.

Growing media[z]	Year 2009		Year 2010		
	Summer	Fall	Spring	Summer	Fall
	(gm^{-2})				
S+P	11.78 abc[y]	5.84 a	9.29 ab	17.98 a	8.24 a
S+So+Ba	12.04 ab	5.31 ab	7.75 ab	16.47 a	5.62 a
S+So	8.80 bc	5.91 a	9.11 ab	16.08 a	6.84 a
S+P+Z	12.6 4a	5.19 ab	7.71 ab	17.07 a	9.33 a
S+Ba	11.05 abc	5.12 ab	7.38 b	15.76 a	7.55 a
S+P+Gp	11.83 abc	5.98 a	9.23 ab	17.59 a	7.52 a
S+So+Ba+Gp	11.96 ab	5.50 ab	8.81 ab	16.21 a	8.97 a
S+So+Gp	13.08 a	6.10 a	9.67 a	16.64 a	7.35 a
S+P+Z+Gp	8.60 c	4.51 b	8.39 ab	16.57 a	7.72 a
S+Ba+Gp	11.24 abc	5.54 ab	9.15 ab	16.74 a	9.49 a

[z]S= sand; P=peat; Ba= bottom ash; So= soil; Z = zeolite; Gp=gypsum.
[y]Means within a column followed by the same letter are not significantly different based on LSD (α =0.05).

may increase the growth of Kentucky bluegrass. Total clipping dry weight of SSoGp was higher than SP and SPGp, whereas the other treatments showed lower clipping yield than SP. Under dry condition, the SP, SSo, SPGp, and SSoGp resulted in higher clipping dry weight than the other treatments, while in wet condition SP, SPZ, and SPGp resulted in higher clipping dry weight. The SP, SSo, SPGp, and SSoGp resulted in higher clipping dry weight than other treatments during fall and spring season.

During the dry period, soil and peat addition resulted in higher clipping yield. This result was similar to the turfgrass visual quality of higher rating from soil and peat addition during the dry period. In wet season, the ability of zeolite to improve turfgrass growth may be related to CEC, nutrient retention and infiltration. Zeolite increased nutrient holding capacity, CEC, and reduced nutrient leaching potential of sand based media (Huang and Petrovic; 1995; Wasura and Petrovic, 2001). Application of gypsum increased the clipping dry weight of SSo and decreased the clipping dry weight of SPZGp. Application of Gypsum did not increase clipping dry weight of SP. Application of gypsum increased the average clipping dry weight of treatments such as SSo, SBa, and SSoBa, but reduced clipping dry weights of SP and SPZ treatments. During the wet period, application of gypsum did not result statistical differences among all treatments.

Growing media SPZGp, SPGp, and SSoGp resulted in longer root of Kentucky bluegrass until the summer of 2010 (Table 7). Growing media SSo, SSoGp, and SPZGp resulted in longer root length of Kentucky bluegrass than SP by 8.2%, 9.2%, and 23.2%, respectively. This result suggested that gypsum applied with zeolite, peat, or soil increased root length of Kentucky bluegrass. However, addition of gypsum with bottom ash decreased the root length of Kentucky bluegrass. Addition of gypsum into SP and SPZ increased root length of Kentucky bluegrass by 10.6 and 37%, respectively. Addition of gypsum to peat, soil, and zeolite increased the root length of Kentucky bluegrass in sand

Table 7. Root length of Kentucky bluegrass in sand base growing media with various amendment material under the saline condition.

Growing media[z]	Year 2009			Year 2010		
	Spring	Summer	Fall	Spring	Summer	Fall
	(cm)					
S+P	6.50 a[y]	9.00 a	13.67 ab	16.67 cde	20.7bcde	34.3 abc
S+So+Ba	5.50 a	7.33 a	9.67cd	12.67 e	18.0 e	20.3 c
S+So	6.17 a	8.83 a	8.50 d	26.00a	18.3 de	33.3 abc
S+P+Z	5.73 a	7.50 a	10.67 bcd	18.00 cd	21.7 bcd	22.3 bc
S+Ba	6.50 a	8.17 a	12.67abc	16.67cde	19.7 cde	35.7 ab
S+P+Gp	6.67 a	8.17 a	15.00 a	19.67bc	23.3 ab	36.3 ab
S+So+Ba+Gp	5.83 a	8.00 a	8.67 d	20.00bc	17.7 e	28.0 abc
S+So+Gp	5.67 a	8.83 a	12.17 abc	23.00 b	22.3 bc	33.0 abc
S+P+Z+Gp	4.67 a	10.17 a	12.17 abc	20.67 bc	26.7 a	41.0 a
S+Ba+Gp	4.83 a	10.17 a	10.33 bcd	14.33 de	17.7 e	29.7 abc

[z]S= sand; P=peat; Ba= bottom ash; So= soil; Z= zeolite; Gp=gypsum.
[y]Means within a column followed by the same letter are not significantly different based on LSD (α =0.05).

based growing media.

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염해지 토양을 기반으로 조성된 모래 지반구조에서 토양개량제 종류에 따른 토양내 염류 집적과 켄터키 블루그래스 (*Poa pratensis* L.)의 생육

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요 약: 본 연구는 염해지 토양을 기반으로 조성된 모래 지반구조에서 토양개량제 종류에 따른 토양내 염류집적과 켄터키 블루그래스의 생육을 평가해 보고자 수행되었다. 시험에 사용된 용기는 바닥에 10 cm 높이로 간척지 논토양을 설치 하였으며, 그 위에 20 cm 높이로 염류 차단을 위해 왕사를 설치하였다. 상토 층은 20 cm 높이로 세사를 설치 하였으며, 상토용 준설모래인 세사와 각각 부피 비율로 1) 피트모스 10% 혼합 처리(SP), 2) 일반토양 10%+bottom ash 10% 혼합 처리(SSoBA) 3) 밭흙(사양토) 20% 혼합 처리(SSo), 4) 피트모스 5%+제올라이트 5% 혼합처리(SPZ), 그리고 5) Bottom ash 20% 혼합처리 (SBa)구를 조성하였다. 또한 각각 처리에는 짚섬 처리구를 추가하여 짚섬의 염 용탈 효과를 조사하였다. 상기 용기들은 전기전도도(ECw)가 3-5 dSm^{-1} 수준인 물에 5 cm 깊이로 침지 처리하였다. 조성된 용기에 켄터키 블루그래스 뗏장을 식재하였다. 관수용수의 염 처리는 전기 전도도가 2 dSm^{-1}의 농도로 하였다. 관수량은 켄터키 블루그래스의 일 증발산량 대비 100% (5.7 $mmday^{-1}$)로 3일 간격으로 살수되었다. 피트모스 5%+제올라이트 5% 처리구에 짚섬 살포는 모래토양의 ECe를 감소시키는 결과를 보였다. 또한 bottom ash 20% 처리구는 토양의 SAR를 감소시키는 결과를 보였다. 유기물 10% 혼합처리(SP)와 밭흙 20% 처리구에 짚섬 살포(SSoGp)시 켄터키 블루그래스의 지상부 건물중이 증가하는 효과를 보였다. 또한 밭흙 20%에 짚섬 혼합구(SSoGp) 및 피트모스 5%+제올라이트 5%에 짚섬 혼합시(SPZGp)는 켄터키 블루그래스의 뿌리 길이가 각각 26.1, 29.5 cm로 길어지는 결과를 보였다. 피트모스 10%(SP) 처리구와 bottom ash 20%+짚섬 혼합구(SBaGp)는 켄터키 블루그래스의 가시적 품질이 각각 7.8, 7.7로 높아지는 결과를 보였다. 밭흙과 bottom ash 처리구에 짚섬을 혼합시 줄기 생육이 증가되었으며, 피트모스, 밭흙 그리고 제올라이트 처리구에 짚섬 혼합시는 지하부 생육이 증가되는 결과를 보였다.

주요어: 켄터키 블루그래스, 염축적, 토양개량제, 염