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Research Report

Effect of Organic Soil Amendments on Establishment Vigor, Seedling Emergence, and Top Growth in Kentucky Bluegrass

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Abstract: Due to limited supplies and expensive importing costs, it is a goal to replace overseas peat with local soil amendments in turf industry of Korea. The study was initiated to compare the performances of five domestic and imported organic soil amendments (OSAs) on establishment characteristics and to provide basic information for root zone composition on sports turf design and construction. The study was conducted in Kentucky bluegrass (*Poa pratensis* L., KB) under greenhouse conditions from March to June in 2008. A total of 25 treatments of OSA + sand were prepared. These amendments were Berger Peat (OMA), Eco-Peat (OMB), G1-Soil (OMC), Premier Peat (OMD), and Supersoil I (OME). Significant differences were observed in establishment vigor, seedling emergence, and top growth. Results varied depending upon the type of OSAs and their rates in rootzone mixtures. OMA reached over 70% in establishment vigor in 5 WAS (weeks after seeding). OMC produced a maximum vigor of approximately 60% in 6 WAS. The OME amendment, however, showed poor performance lower than 30% in establishing KB turf until 8 WAS. There were considerable variations of top growth, being 3.8 to 14.5 cm. Greater differences in top growth resulted from OME mixtures. Shoot growth orientation in KB is also influenced by OSAs. In general, optimum mixing rate was considered as 10 to 20% for establishment vigor and 20 to 40% for top growth. Considering overall responses to establishment vigor, seedling emergence, and shoot growth, both local OMC and overseas OMD are considered as the useful soil amendments applicable for sports turfs. Domestic OME amendment would be applied for a low maintenance turfs such as rough and utility areas due to greater shoot growth. Information on these amendments would be of practical use for sports turf design and construction. Repeated experiments and field performance test are required to evaluate these OSA effect on other major turfgrass species and also to determine local OSA as imported peat substitute.

Additional key words: peat, plant height, rootzone mix, turfgrass survival, vertical shoot growth

Introduction

High-quality sports turfs are rarely closed for sufficient time for turf recovery and/or for certain maintenance practices. This is true for most cases in Korea, especially in sports turf areas such as world cup soccer stadiums and private membership golf courses. They are subjected to regular watering, frequent mowing, and intense traffic (Kim, 2006; KISS, 1998). To maintain a high-quality turf under these situations is becoming a practical challenge for the Korean turf managers. If sports turfs are not properly constructed, they easily become compacted leading to declining growth, undesirable turf quality, and unacceptable playing conditions (Beard, 1973).

The quality sports turfs have been mainly established in sand soil systems to solve soil compaction issues (Cockerham, 1994; Puhalla et al., 2002). When establishing sports turfs in sandy soils, soil amendments are incorporated into rootzone mixes for golf tee, fairway and putting greens, and soccer fields. This application leads to beneficial changes in soil properties, resulting in improvements of drainage, water holding capacity, and nutrient retention (Kerek, 2003; Koh et al., 2006; Li et al., 2000; Lucas et al., 1965). Other improvements include better germination rate, higher seedling survival, and turfgrass quality enhancement.

Soil amendments are classified as two types according to the raw materials used. They may be inorganic or organic amendments (Puustjarvi and Robertson, 1975). Organic

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soil amendments (OSA) have beneficial effects on improving the soil physical and chemical property (Landschoot and McNitt, 1997). It also provides suitable environment which leads to increased beneficial microorganisms (Ham et al., 1993; Puustjarvi and Robertson, 1975), disease suppression (Liu et al., 1995), increased turf growth (Kim et al., 1998) and fertilizer and organic matter substitute (Garling and Boehm, 2001; Logan and Harrison, 1995). Organic matter in soil amendments is desirable for soil structure, soil aeration, moisture movement, nutrient availability, and ecosystem sustainability (Bandaranayake et al., 2003; Kim, 2007). It is a good element in turfgrass soil system as a function of nutrient sources that need for turfgrass growth (USGA Green Section Staff, 1973).

Peat is the most common organic amendment used in turf industry around the world. It is a main organic source in high-quality turf construction of golf courses and sports fields. However, peat is a nonrenewable resource in limited supply (Liu et al., 2005; Waltz and McCarty, 2005). Also, it is very expensive due to transportation costs for importing from North America. Furthermore, it is hard to secure it at right time to meet construction schedule due to unexpected delay from customs and quarantine process. Interest in peat substitutes has been long increased in Korea. Use of composted organic materials from locally available sources is one of the feasible options, but domestic soil amendments are not used extensively due to a lack of information on their performance on soil properties and turfgrasses. Accordingly, performance tests for domestic amendments are of a great interest. Furthermore, comparison studies between local and overseas amendments are practically needed for turf industry in Korea.

Kim (2009a, 2009b) reported that domestic soil amendments affected the growth and quality of Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.). In a study by Koh et al. (2006) organic amendments from local animal manure and sawdust increased the root growth and turf quality of Korean lawngrass (*Zoysia japonica* Steud.) and Kentucky bluegrass. Some data are also available on the growth responses in rootzone mixes of sand plus organic amendments or mineral nutrients (Choi et al., 1994; Ham et al., 1993, 1997; Kim, 2011, 2012; Kim and Park, 2011; Kim et al., 1992, 1998, 1999, 2003; Koh et al., 2006; Lee, 2003). These experiments, however, were only conducted with single soil amendment or rootzone mixture with imported peat. No previous studies have been made in comparing local amendments with overseas peats for an establishing purpose.

The objectives of this study were to evaluate both domestic and imported soil amendments on establishment vigor, seedling emergence, and top growth, to compare their performance for rootzone mixes, to determine mixing rate for each OSA, and finally to provide basic information for rootzone mixture on sports turf design and construction with these amendments.

Materials and Methods

Treatments and Experimental Design

The study was conducted in Kentucky bluegrass (KB, *Poa pratensis* L.) ‘Blacksburg’ (Turf-Seed, Inc., Hubbard, OR, USA) under greenhouse conditions from March to June in 2008. Treatments were composed of mixtures of five organic matter amendments and sand. In the experiment two imported and three domestic soil amendments were selected as organic sources for rootzone mixes. These

Table 1. Source, origin, and chemical properties of organic soil amendments used for rootzone mix in the study.

Organic soil amendment[z]	Source	Origin	Chemical properties[y]			
			pH	EC ($dS\cdot m^{-1}$)	CEC ($me\cdot 100\ g^{-1}$)	OM (%)
OMA	Berger Peat	Canada	3.78	0.115	124.6	95.8
OMB	Eco-Peat	Korea	5.40	3.830	74.8	90.6
OMC	G1-Soil	Korea	6.13	2.100	38.3	66.5
OMD	Premier Peat	Canada	3.60	0.171	127.6	94.7
OME	Supersoil I	Korea	6.41	4.590	81.9	77.8

[z]OMA, Berger Peat (Les Tourbières Berger Ltee, Quebec, Canada); OMB, Eco-Peat (Nature & Environment Co., Ltd., Seoul, Korea); OMC, G1-Soil (Nature & Environment Co., Ltd., Seoul, Korea); OMD, Premier Peat (Premier Tech Horticulture, Quebec, Canada); OME, Supersoil I (Jookjoo Fertilizers, Iljuk, Kyounggi, Korea).
[y]EC, electrical conductivity; CEC, cation exchange capacity; OM, organic matter.

Table 2. A total of 25 treatments for investigating the effect of organic soil amendments on establishment vigor, seedling emergence, and top growth of Kentucky bluegrass in the study.

Treatment No.	Organic soil amendment[z] (OSA)	Rootzone mixture of OSA and sand[y] (%, v/v)
1	OMA 10	Berger Peat 10 + silica sand 90
2	OMA 20	Berger Peat 20 + silica sand 80
3	OMA 30	Berger Peat 30 + silica sand 70
4	OMA 40	Berger Peat 40 + silica sand 60
5	OMA 50	Berger Peat 50 + silica sand 50
6	OMB 10	Eco-Peat 10 + silica sand 90
7	OMB 20	Eco-Peat 20 + silica sand 80
8	OMB 30	Eco-Peat 30 + silica sand 70
9	OMB 40	Eco-Peat 40 + silica sand 60
10	OMB 50	Eco-Peat 50 + silica sand 50
11	OMC 10	G1-Soil 10 + silica sand 90
12	OMC 20	G1-Soil 20 + silica sand 80
13	OMC 30	G1-Soil 30 + silica sand 70
14	OMC 40	G1-Soil 40 + silica sand 60
15	OMC 50	G1-Soil 50 + silica sand 50
16	OMD 10	Premier Peat 10 + silica sand 90
17	OMD 20	Premier Peat 20 + silica sand 80
18	OMD 30	Premier Peat 30 + silica sand 70
19	OMD 40	Premier Peat 40 + silica sand 60
20	OMD 50	Premier Peat 50 + silica sand 50
21	OME 10	Supersoil I 10 + silica sand 90
22	OME 20	Supersoil I 20 + silica sand 80
23	OME 30	Supersoil I 30 + silica sand 70
24	OME 40	Supersoil I 40 + silica sand 60
25	OME 50	Supersoil I 50 + silica sand 50

[z]OMA, Berger Peat (Les Tourbières Berger Ltee, Quebec, Canada); OMB, Eco-Peat (Nature & Environment Co., Ltd., Seoul, Korea); OMC, G1-Soil (Nature & Environment Co., Ltd., Seoul, Korea); OMD, Premier Peat (Premier Tech Horticulture, Quebec, Canada); OME, Supersoil I (Jookjoo Fertilizers, Iljuk, Kyounggi, Korea).
[y]Sand, pure silica sand meeting USGA recommendations in Table 3, which consists of sand over 90% between 0.15 and 1.0 mm in particle size.

amendments were OMA (Berger Peat: Les Tourbières Berger Ltee, Quebec, Canada), OMB (Eco-Peat: Nature & Environment Co. Ltd., Seoul, Korea), OMC (G1-Soil: Nature & Environment Co. Ltd., Seoul, Korea), OMD (Premier Peat: Premier Tech Horticulture, Quebec, Canada), and OME (Supersoil I: Jookjoo Fertilizers, Iljuk, Kyounggi, Korea). Information on their source, origin, and chemical properties were described in Table 1.

Treatments were arranged with these five amendments at five volume percentages (10, 20, 30, 40, and 50%; v/v). The remaining soil for each treatment was sand. Accordingly, a total of 25 treatments were prepared in the study (Table 2). Pure silica sand meeting USGA putting green specifications was used (Table 3). All treatments were placed in plot with a 0.2 m × 0.2 m (0.04 m^2 surface area). A randomized complete block design was used with six replications.

At a seeding rate of 12 $g \cdot m^{-2}$ KB seeds were sown in plots. It has been extensively used for residential and sports turf areas in Korea since the 2002 Korea/Japan FIFA World Cup Soccer (KOWOC, 2000). A preliminary germination test was carried out in order to use a good germination of KB cultivar. Such cultivars as ‘Award’, ‘Blacksburg’, ‘Excursion’, and ‘Midnight’ were tested with 4 replications under a controlled incubator. Alternative conditions was applied, consisting of 8 h light at 25°C and 16 h dark at 15°C (The Lawn Institute, 1991). The cultivar ‘Blacksburg’ was selected after one-month test, based on over 90% germination rate.

Turf was grown under greenhouse conditions with day/night temperatures of approximately 30/15°C. Water was applied as needed to prevent drought stress. The turf was unmown during the study. Whole plots were topdressed with straight silica sand and treated with fungicide on a curative basis.

Measurements and Data Analysis

Data were collected on establishment vigor, seedling emergence, and top growth. Seedling emergence was weekly investigated for 8 weeks and described as a cumulative pattern. At the end of study establishment vigor was deter-

Table 3. Particle size distribution of silica sand used for rootzone mix with organic soil amendments in the study.

Particle size (mm)	Particle size distribution (%)							
	Gravel (2.0-3.4)	Very coarse (1.0-2.0)	Coarse (0.5-1.0)	Medium (0.25-0.5)	Fine (0.15-0.25)	Very fine (0.05-0.15)	Silt (0.002-0.05)	Clay (< 0.002)
USGA[z] Spec.	≤ 3%	≤ 7%	≥ 60%		≤ 20%	≤ 5%	≤ 5%	≤ 3%
Sand	1.00	2.25	87.00		7.00	1.50	0.25	0.04

[z]USGA, United States Golf Association.

mined as the number of seedlings. Top growth was also evaluated as plant height with six subsamples per replication. An analysis of variance was performed for data for treatments using the General Linear Model procedures and the Statistical Analysis System (SAS Inst., Inc., 2001). Mean separation was made with Duncan's multiple range test at $P \leq 0.05$ to detect differences among treatments (Steel and Torrie, 1980).

Results and Discussion

Establishment Vigor

Significant differences were observed in establishment vigor, seedling emergence, and top growth. Results varied depending upon the type of OSAs and their rate in rootzone mixtures. Data for turfgrass establishment vigor were described in Fig. 1. At the end of study the overall establishment vigor ranged between 3.0 and 73.3%. The OMA mixtures (Treatments 1 to 5) had establishment vigor of 35.3 to 73.3%. The greatest vigor of 73.3% was observed from plots in OMA 10. But the lowest value of 35.3% was also observed from the OMA 40 mixture. Treatments 6 to 10 with OMB produced 40.3 to 53.0% in establishment vigor. The highest ratings were 53.0 and 52.3% from plots in OMB 10 and OMB 20 mixtures, respectively. But the lowest vigor was 40.3% which was associated with OMB 50.

In plots of OMC mixtures (Treatments 11 to 15), the vigor varied between 34.7 and 59.0%. The greatest vigor of 59.0% was from the OMC 10, whereas the lowest was 34.7% from the OMC 50. Treatments 16 to 20 with OMD mixtures had a range of 17.0 to 49.3% in establishment vigor. The highest was 49.3%, which was associated with the OMD 10. But the lowest was 17.0% from plots in OMD 50 mixture. From the OME plots (Treatments 21 to 25), establishment vigor ranged from 3.0 to 30.7%. Both OME 10 and 20 mixtures produced the greatest vigor of 29.0 to 30.7%. The lowest value of 3.0% was observed in plots of OMD 50.

These results indicated the establishment vigor in KB differed with OSAs and their rate in rootzone mixes. Also, the establishment trend was weekly evaluated as seedling emergence and described as a cumulative pattern (Fig. 2). The pattern greatly varied according to the type of OSAs with time after seeding. Among five OSAs tested, overseas OMA was regarded as the most effective one, reaching over 70% of establishment vigor at OMA 10 just in 5 WAS. Domestic OMC was also a good soil amendment, producing a maximum vigor of approximately 60% at OMC 10 in 6 WAS. However, the OME amendment showed poor performance lower than 30% in establishing KB turf until 8 WAS.

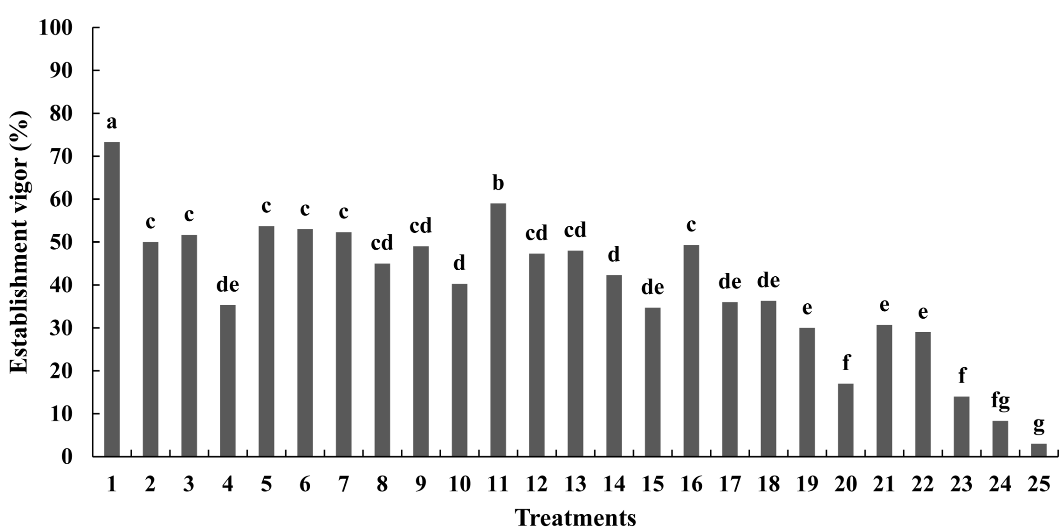

Fig. 1. Establishment vigor of Kentucky bluegrass at the end of study which was grown under greenhouse conditions. Treatments were comprised of five organic matter amendments and sand. The amendments were OMA (Berger Peat: Les Tourbières Berger Ltee, Quebec, Canada), OMB (Eco-Peat: Nature & Environment Co., Ltd., Seoul, Korea), OMC (G1-Soil: Nature & Environment Co., Ltd., Seoul, Korea), OMD (Premier Peat: Premier Tech Horticulture, Quebec, Canada), and OME (Supersoil I: Jookjoo Fertilizers, Iljuk, Kyounggi, Korea). A total of 25 treatments were arranged with these amendments at five volume percentages (10, 20, 30, 40, and 50%; v/v) as described in Table 2. The remaining soil for each treatment was a pure silica sand meeting USGA putting green specifications. Bars with different letters are significantly different based on Duncan's multiple range test at P = 0.05.

Other amendments, OMB and OMD, had an intermediate rate of establishment vigor, producing 50% or so in 8 WAS.

For the best rootzone mix, the optimum rate was variable with OSA in the study. In general, 10 to 20% could be recommended for fast establishment vigor. Higher rates over 40% resulted in very poor establishment. It has been concluded by researchers (Glasgow et al., 2005; Magni et al., 2005) that composted organic materials are beneficial in turf establishment by increasing water holding capacity and nutrient retention. A reason for this is that hydrophilic nature can explain the greater water retention from the compost-amended soil (Magni et al., 2005). Bethke (1988), however, reported that excessive peat caused chemical and

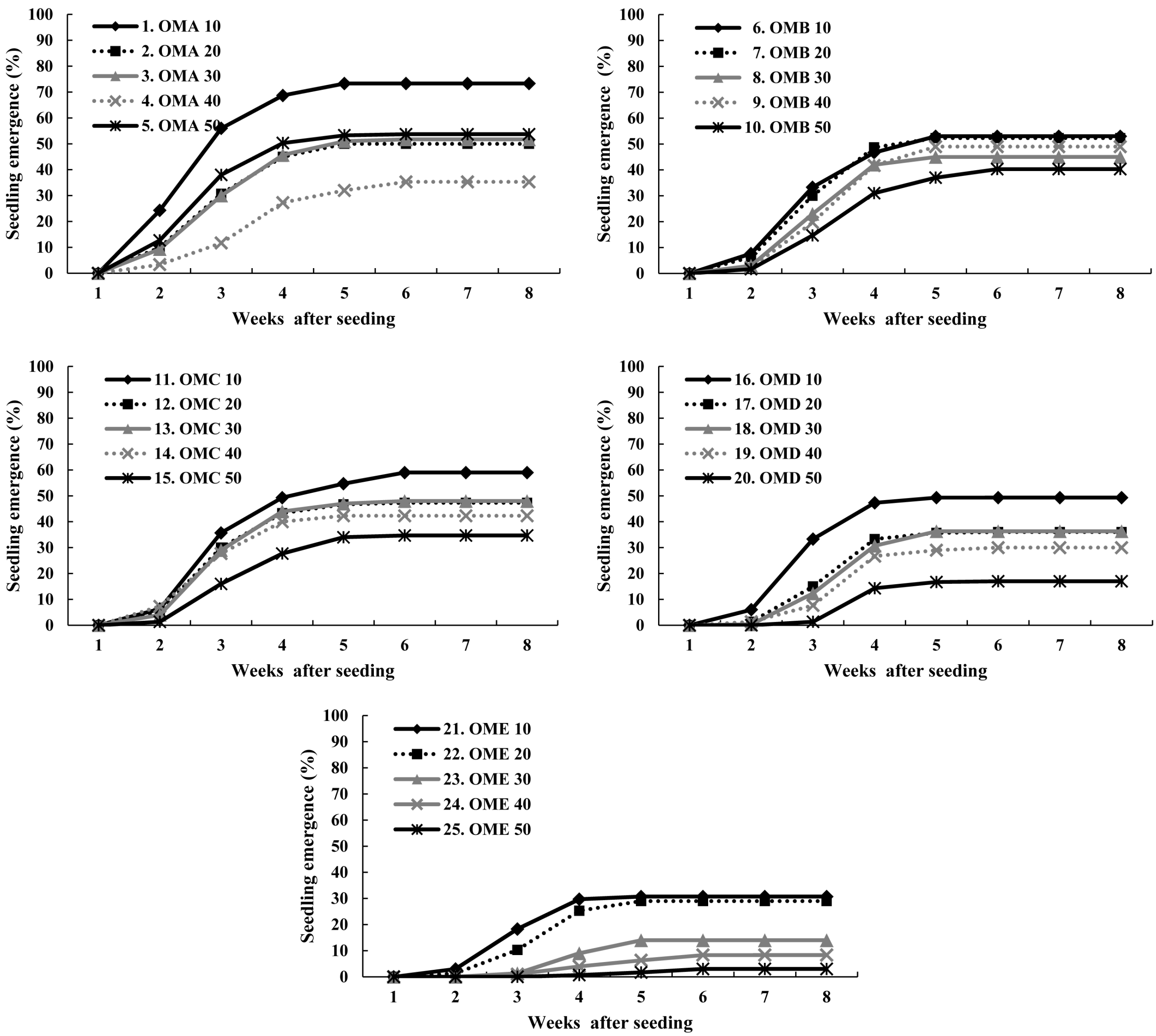

Fig. 2. Cumulative seedling emergence of Kentucky bluegrass which was grown under greenhouse conditions. Treatments were comprised of five organic matter amendments and sand. The amendments were OMA (Berger Peat, Les Tourbières Berger Ltee, Quebec, Canada), OMB (Eco-Peat, Nature & Environment Co., Ltd., Seoul, Korea), OMC (G1-Soil, Nature & Environment Co., Ltd., Seoul, Korea), OMD (Premier Peat, Premier Tech Horticulture, Quebec, Canada), and OME (Supersoil I, Jookjoo Fertilizers, Iljuk, Kyounggi, Korea). A total of 25 treatments were arranged with these amendments at five volume percentages (10, 20, 30, 40 and 50%; v/v) as described in Table 2. The remaining soil for each treatment was a pure silica sand meeting USGA putting green specifications.

physical properties of rootzone mix to be a poor turf growth. Organic matter in rootzone exceeding a certain level can cause blockage of macropores to deteriorate some physical properties such as drainage, aeration, and water retention. This turns to increased disease and reduced rooting (Adams and Saxon, 1979). During the study we observed some disease occurrence in higher-mixed plots of 40 to 50% of OSAs.

Top Growth

Significant differences were found in top growth according to the type of OSAs and their rates. There were considerable variations of KB shoot growth, being 3.8 to 14.5 cm (Fig. 3). The OMA mixtures ranged between 4.5 and 6.5 cm in plant height. In general, the higher the OMA rate, the longer the plant height. Accordingly, plots over OMA 30 had a longer shoot growth, resulting in 6.0 to 6.5 cm of height. The shortest growth was associated with OMA 10, being 4.5 cm. Plots mixed with OMB produced 4.6 to 5.8 cm in plant height. The highest growth of 5.8 cm was associated with OMB 40. The second height was 5.3 cm in plots of OMB 50.

Evaluation on the OMC mixtures showed that plant height ranged between 4 and 5 cm. The greatest height of 4.6 cm was observed from plots in OMC 20. But the shortest was 4.0 cm from both OMC 10 and 50 mixtures. Plots amended with OMD showed 3.8 to 4.8 cm in plant height. The highest height of 4.8 cm was associated with OMD 40. But the lowest was from plots in OMD 50, being 3.8 cm of plant height. From the OME plots it was greatly variable from 7.8 to 14.5 cm. The OME 30 mixture had the greatest height of 14.5 cm. The second greatest value was 12.0 cm from OME 40. But the shortest was 7.8 cm, being observed with OME 10.

This study showed that KB top growth was greatly variable with OSAs and their rate. In general, optimum rates were considered as 20 to 40% for a vigorous shoot growth. Among five OSAs evaluated, there was a little difference in shoot growth with an exception of OME amendment, which resulted in much more shoot growth than others.

As a rhizomatous-type of growth habit, KB is more prone to horizontal growth (Beard and Beard, 2005; Turgeon, 2005), being shorter in plant height as compared with bunch-type turfgrass such as perennial ryegrass and tall fescue (*Festuca arundinacea* Schreb.). This study, however, demonstrated that shoot growth orientation is also influenced by OSAs in KB. In other words, it might grow more vertically depending on the kind of OSAs used. Consequently, it is practically necessary to consider a specific OSA for a turf

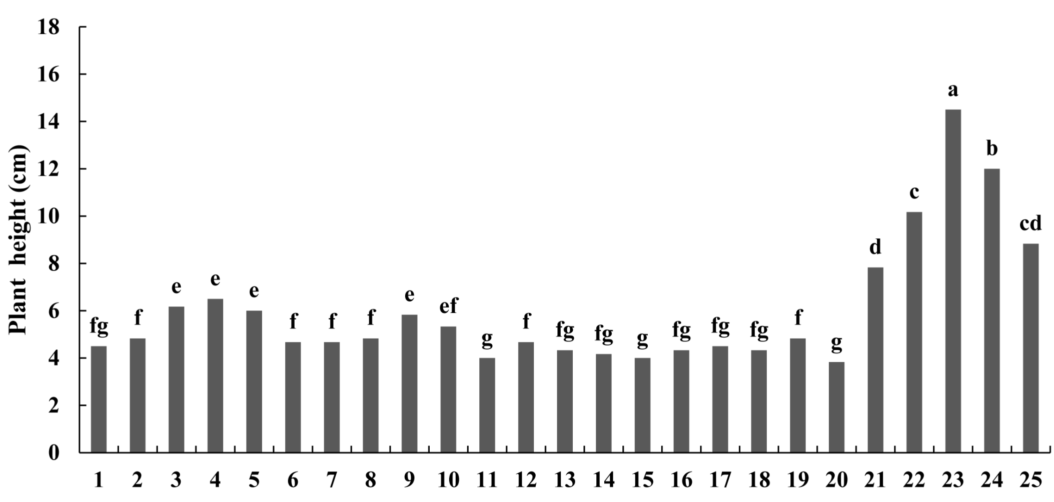

Fig. 3. Plant height of Kentucky bluegrass at the end of study which was grown under greenhouse conditions. Treatments were comprised of five organic matter amendments and sand. The amendments were OMA (Berger Peat, Les Tourbières Berger Ltee, Quebec, Canada), OMB (Eco-Peat, Nature & Environment Co., Ltd., Seoul, Korea), OMC (G1-Soil, Nature & Environment Co., Ltd., Seoul, Korea), OMD (Premier Peat, Premier Tech Horticulture, Quebec, Canada), and OME (Supersoil I, Jookjoo Fertilizers, Iljuk, Kyounggi, Korea). A total of 25 treatments were arranged with these amendments at five volume percentages (10, 20, 30, 40 and 50%; v/v) as described in Table 2. The remaining soil for each treatment was a pure silica sand meeting USGA putting green specifications. Bars with different letters are significantly different based on Duncan's multiple range test at P = 0.05.

Table 4. Summary of overall performance and optimum rate for rootzone mix on the growth characteristics by organic soil amendment (OSA) in Kentucky bluegrass in the study.

Organic soil amendment[z]	OSA performance[y]				Optimum OSA rates (%, v/v)	
	Establishment vigor	Shoot growth	Overall rating	Suggested intensity for maintenance	Establishment vigor	Shoot growth
OMA	+++++	++	+++	medium	10	30-50
OMB	+++	++	++	low	10-20	40
OMC	++++	+	+++++	high	10	20
OMD	+++	+	++++	high	10	40
OME	+	+++++	+	very low	10-20	30-40

[z]OSA, organic soil amendment; OMA, Berger Peat (Les Tourbières Berger Ltee, Quebec, Canada); OMB, Eco-Peat (Nature & Environment Co., Ltd., Seoul, Korea); OMC: G1-Soil (Nature & Environment Co., Ltd., Seoul, Korea); OMD, Premier Peat (Premier Tech Horticulture, Quebec, Canada); OME: Supersoil I (Jookjoo Fertilizers, Iljuk, Kyounggi, Korea).
[y]OSA performance: + = low; ++ = low to medium; +++ = medium; ++++ = medium to high; +++++ = high.

establishment purpose. For example, increased plant height is more desirable for a rough area in golf course, while lowered plant height much better for a high-density areas such as tees and fairway (Beard, 2004).

At this study the greater shoot growth was not necessarily related with the higher OSA rate. In particular, as for the OMD and OME mixtures, we found that the highest rate of 50% in mixtures significantly led to a poorer shoot growth. This could be explained by the fact that optimum mixing increases water and nutrient retention, resulting in good growth. But its excessive mixing alters soil physical and chemical balance in rootzone mix leading to poor turf growth. As explained previously, organic matter beyond a certain point can cause macropore blockage to impair drainage, aeration and water retention. In turn it might increase disease and reduce rooting (Adams and Saxon, 1979). Waddington (1992) stated that the soil amendment effect could be varied with mixing rate and method and mixing soil. Bethke (1988) concluded that a general mixing ratio for peat ranged 5 to 20%, but excessive mixing led to poor turf growth by modifying soil physical and chemical properties of rootzone mix.

In this study results demonstrated the differences in establishment vigor, seedling emergence, and top growth according to OSAs and their rates. This conclusion is supported by other researchers. In a study under greenhouse conditions with warm-season turfgrasses, Liu et al. (2005) demonstrated increased clipping yields three times and improved the turf quality in rootzone sand at 15% (v/v) with compost organic materials. Also, research with cool-season grass indicated that turf growth and quality were influenced by organic amendment in perennial ryegrass and KB (Kim, 2009a, 2009b).

Optimum rate for rootzone mix may be dependent on the type of OSA. Reasonable mixing rates are considered as 10 to 20% for establishment vigor and 20 to 40% for shoot growth, regardless of OSAs (Table 4). Several researchers reported various threshold levels of organic matter in sand-based soil systems. It has been concluded by the same author that proper levels for surface organic matter in rootzone by weight was lower than 3-4% (Carrow, 1998) and 4-5% (Carrow, 2004). Adams and Saxon (1979) reported that organic matter levels over 12% initiated to dominate rootzone performance. But these conclusions for organic matter levels were based on weight basis. The recommendation would be variable when compared with a volume-to-volume basis, being possibly higher rates in mixtures. Alkire (2007) suggested organic matter with 10-20% of volume should be used to amend the sand content within the sports turf rootzone mix. Therefore, it was considered that its optimum rate varies with OSAs as well as growth characteristics. This means that unknown OSA should be tested for a planting purpose before an on-site application. In a study on the effect of rootzone mixes on the growth of creeping bentgrass (*Agrostis palustris* Huds.) in putting green (Kim et al., 1999), they concluded that a proper rate for rootzone mix should be decided, based on both turf growth and soil physical properties.

Considering overall responses such as establishment vigor, seedling emergence, and top growth, both local OMC and imported OMD amendments are considered as the useful soil amendments applicable for sports turfs. The amendment OMA is also a good source for rootzone mix. The amendment OME would be applied for a low maintenance turfs such as rough and utility areas due to greater shoot growth. Information on these amendments from this study would be of a practical use for sports turf design and construction. A further study would be useful for evaluating OSA effects on growth characteristics of other major turfgrasses. Additional information from repeated experiments and field performance test is also needed for these OSAs to determine proper OSA and rate for sports turf application in Korea as an expensive, importing peat substitute.

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