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Influence of the Composted Liquid Manure on the Turf Growth of Zoysiagrass (*Zoysiagrass japonica*) and Soil Properties

Ju Hyun Ryu[1], Suon Kyu Ham[2], Sang-Kook Lee[3], and Ki Sun Kim[1,4]*

[1]*Department of Horticultural Science & Biotechnology, Seoul National University, Seoul 151-921, Korea*
[2]*Turfgrass Research Institute, Daejung Golf Engineering Co., Ltd, Incheon 400-340, Korea*
[3]*Department of Biotechnology, Hoseo University, Asan 336-795, Korea*
[4]*Research Institute of Agriculture and Life Sciences, Seoul National University, Seoul 151-921, Korea*

ABSTRACT. This study was conducted to investigate the effects of composted liquid manure (CLM) on soil properties and turf quality of zoysiagrass. The CLMs were produced at 5 facilities for livestock excretions treatments located in Cheongwon, Gunwi, Iksan, Nonsan, and Yeoju in Korea, respectively. Field experiments were conducted at 5 golf courses and a sod farm located near each facility for livestock excretion treatments. Chemical fertilizer (CF) with N at 12 g m^{-2} $year^{-1}$ and CLMs were applied four times, respectively. The constituents of the different CLMs were variable based on when and where the fertilizer was produced. Soil K content significantly increased when the soil was treated with CLMs. The soil treated with CF showed a higher content of total P than that treated with CLM. CF and CLMs treatments significantly increased the turf color index compared with control. Tiller density and shoot dry weight of fertilized plots were also higher than those of non-fertilized plots. However, there was no significant difference in turf color index and tiller density among plots treated by CLMs or CF. The results of this study demonstrated that CLMs could be a substitute for CF.

***Key words*:** Compost, Natural recycling agriculture, Tiller density, Turf color index

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***Corresponding author:** Phone) +82-2-880-4561, Fax) +82-2-873-2056; E-mail) kisun@snu.ac.kr

Introduction

There has been interest in composted manure owing to its contribution to plant growth through its effect on the physical, chemical, and biological properties of soil in recent days (Cheng et al., 2007). However, several obstacles prevent widespread use of livestock excretions as a suitable fertilizer, including excess nitrates, phosphates, salts, undesirable microorganisms, pathogens, as well as a unwant odor (Eghball and Power, 1999). Thus, there is a significant need for a proper disposal process for livestock excretions employing both biological and physicochemical methods (Kushwaha et al., 2010).

In Korea, in order to manage livestock excretions that seriously affect the agricultural environment as well as facilitate utilization of livestock excretions as nutrient resources, the government has promoted a measure for natural circulation in agriculture (ME, 2009). All treatment facilities presently produce composted liquid manure (CLM) as well as compost. CLM has been produce by several treatment procedures according to the type of separation membranes and filters and the temperature conditions, such as membrane bioreactor method, continuously aerated bioreactor, slurry composted and biofiltering and so on. They are mostly odorless, homogeneous, pure, biologically humus-like stable organic liquid material with a low nitrate concentration (Ham et al., 2010).

Slurry composted and bio-filtered liquid fertilizer (SCB), a kind of CLM, has been applied as a partial replacement for chemical fertilizer (CF) on many plants such as red pepper, tomato, forage crops, cucumber, yellow poplar, and pine trees (Ham et al., 2010; Jo et al., 2010; Kim et al., 2011; Lim et al., 2008; Park et al., 2011; Seo et al., 2010). In addition, researchers have used SCB during fertilization to promote growth of both Creeping bentgrass and Kentucky bluegrass (Ham et al., 2010) and zoysiagrass (Kang et al., 2010; Park et al., 2012). These studies reported that application of SCB with a small amount of CF or more than twofold application of SCB resulted in turfgrass whose quality was equal to or higher than that of CF treated plots, and without evidence of fertilizer injury. However, there have been few studies that have attempted to use other CLMs for the turfgrass maintenance except SCB.

The amount of CLM to be applied to the turf plot depends on the fermentation of CLM, the turfgrass growth, and environmental conditions. The amount of nitrogen (N) in composted liquid manure was less than that in non-composted liquid manure. Because, in our previous study, the easily mineralizable nitrogen in CLM has mostly been converted to inorganic forms (data not shown), research is needed to investigate the impact of CLM fertilization on soil chemical properties. However, there is limited information on the available about effects of fertilization with CLM on soil chemical characteristics.

Thus, this was carried out to i) examine the change of chemical constituents of several types of CLM by the process to make CLM products; ii) compare the chemical properties of soil in sites treated by CLM; and iii) determine the effects of CLMs on turf quality.

Table 1. Location of experiment sites and livestock excretion treatment facilities and treatment methods of each facilities.

Experiment site	CLM[z] production facilities	Treatment method
Chungbuk (CB)	Cheongwon	Physical-Chemical method
Chungnam (CN)	Nonsan	Activated sludge method
Gyeongbuk (GB)	Gunwi	Continuously aerated bio-reactor
Gyeonggi (GG1)	Yeoju	Aerobic Fermentation
Gyeonggi (GG2)	Yeoju	Aerobic Fermentation
Jeonbuk (JB)	Iksan	High temperature aeration

[z]CLM: Composted Liquid Manure.

Materials and Methods

CLMs and site description

The used CLMs in the study were produced at 5 different treatment facilities of livestock excretions located in Korea (Table 1). The experiment was conducted at 5 golf courses and 1 sod farm near each facility for livestock excretion treatment in 2013. Experimental plots were established with medium-leaf ecotype of zoysiagrass (*Zoysia japonica*). The farm and the golf course names will not be mentioned in this paper, and a code assigned to each will be used to avoid disclosure. All plots were fertilized three or four times with N at 3 g m^{-2} at May 1 (GG1 and GG2), Jun. 21, Jul 13, and Sep. 5 in 2013. CLM was applied at 3 L m^{-2}, since the mean of the total nitrogen concentration of CLMs in 2012 was about 0.98 g L^{-1}. Chemical fertilizer (CF) was fertilized at 3 L m^{-2} with Technigro fertilizer (20-20-20, Fisons Horticulture Inc, Warwick, NY, USA).

Analysis of CLMs and soil

The chemical constituents of CLMs used in 2012 and 2013 are presented in Tables 2. Total dissolved solids (TDS), pH, and EC were measured using a portable pH / EC / TDS / Temperature Meter (HI9811-5, Hanna instruments Inc, Woonsocket, RI, USA) before CLM application. Chemical analysis was performed at the National Instrumentation Center for Environmental Management (Seoul National University, Seoul, Korea). Total N was measured by using the Kjeldahl method (Bremner, 1996). Other nutrients were quantified using inductively coupled plasma spectrophotometry (ICP; 730-ES, Varian, USA) after acid digestion (NIAST, 2000).

For the determination of soil properties, we took soil samples using a hole cutter and prepared the soil from 3 cm to 10 cm below thatch layer of samples by using a knife.

Table 2. Chemical properties of composted liquid manure produced from livestock excretions treatment facilities in 2013.

	pH (1:5)				EC[z] (dS m^{-1})				TDS (mg L^{-1})				T-N (mg L^{-1})				Av. P (mg L^{-1})				Ex. K (mg L^{-1})			
Location	Jun.[y]	Jul.	Sep.	Mean	Jun.	Jul.	Sep.	Mean	Jun.	Jul.	Sep.	Mean	Jun.	Jul.	Sep.	Mean	Jun.	Jul.	Sep.	Mean	Jun.	Jul.	Sep.	Mean
CW[x]	8.8	8.4	7.8	8.3	1.03	1.18	1.17	1.13	5,450	6,670	6,940	6,353	814	486	642	647	193	185	163	180	982	2,192	2,923	2,032
GW	8.0	7.8	7.9	7.9	1.43	1.60	1.45	1.49	8,150	8,750	8,230	8,377	839	1,480	2,459	1,593	52	103	227	128	2,686	2,817	2,752	2,752
IS	8.4	8.8	8.6	8.8	1.52	1.68	1.51	1.57	8,910	9,000	8,780	8,895	664	1,348	2,069	1,360	223	179	410	271	3,370	2,347	2,548	2,755
NS	8.3	8.2	7.7	8.2	1.03	0.96	0.85	0.95	6,150	5,450	4,860	5,268	2,740	1,550	642	1,644	114	209	163	162	1,479	1,760	2,923	2,054
YJ	8.7	8.3	8.1	8.4	0.99	0.84	0.88	0.90	5,690	4,980	5,020	5,038	555	708	837	700	17	19	94	41	977	1,466	1,510	1,436
Mean	8.4	8.3	8.0	8.4	1.20	1.25	1.17	1.21	6,870	6,970	6,766	6,648	1,122	1,114	1,330	1,217	120	139	211	126	1,899	2,116	2,531	2,084

[z]EC: Electrical conductivity; TDS: total dissolved solid; T-N: total nitrogen; Av. P: available P_2O_5; Ex. K: exchangeable potassium.
[y]Sampling date was Jun. 21, Jul 13, and Sep. 5 in 2013.
[x]CW: Cheongwon; GW: Gunwi; IS: Iksan; NS: Nonsan; YJ: Yeoju.

Parameters of each CLM sample tested included soil pH, EC, organic matter (OM), total N, available P (Av. P), and exchangeable K (Ex. K). Soil pH and EC were investigated in a 1:5 suspension. OM content was measured by dichromate oxidation and titration with ferrous ammonium sulfate (Walkley and Black, 1934). Av. P in soil was extracted by method of Lancaster (NIAST, 2000), and Ex. K was extracted with 1N-ammonium acetate. The extracted solutions were analyzed with ICP after dilution.

Turf quality and growth

Turf quality was presented by the mean of the turf color index of 10 random locations in the experimental plots using a turf color meter (TCM 500, Spectrum Technologies, Inc., Plainfield, IL, USA) before the application of CF and CLM. Experimental plots were managed with conventional management programs except for fertilization and fungicide applications at each experimental location. For turf growth measurement, plant samples were collected using a 10-cm-diameter hole cutter. Zoysiagrass tillers were counted to estimate tiller density and then were oven dried at 80 for 48h to estimate above-ground biomass per 1 m^2 (Stiglbauer et al., 2009).

Statistical analysis

At each site, treatment plots were arranged in a split-plot design with fertilization (versus non-fertilization) as the parameter for the sub-plot (1.0 by 2.0 m). There were three blocks leading to three replicate plots per treatment. All statistical analysis was conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA). Turf quality and LSD (least significant difference) of 5% level were calculated by a one way ANOVA. Group differences between the CF and CLM treatment in soil chemical properties were compared by t-tests.

Table 3. Chemical properties of the experimental plot after the fertilization in 2013.

Site	Sample month[z]	pH		EC[y] (ds m^{-1})		OM (%)		T-N (%)		P (mg kg^{-1})		K (mg kg^{-1})	
		CF[x]	CLM	CF	CLM	CF	CLM	CF	CLM	CF	CLM	CF	CLM
CB[x]	Aug.	6.4	6.7	2.6	2.0	1.5	2.5	0.16	0.19	413	207	0.6	1.7
	Oct.	7.1	6.8	1.1	1.8	2.8	2.5	0.22	0.18	289	228	1.4	1.4
CN	Aug.	6.7	6.6	1.8	2.9	2.5	2.2	0.52	0.17	210	326	1.6	2.0
	Oct.	7.0	7.1	0.8	1.0	1.8	1.9	0.24	0.20	273	265	2.1	1.2
GB	Aug.	6.2	6.3	1.0	1.5	0.5	3.2	0.09	0.29	164	158	0.5	1.4
	Oct.	6.2	6.2	1.9	2.2	2.1	1.6	0.22	0.27	218	170	1.6	1.6
GG1	Aug.	6.7	6.3	2.1	2.7	1.6	2.8	0.24	0.26	177	371	1.5	2.2
	Oct.	6.7	6.7	2.0	1.8	2.0	3.1	0.12	0.12	349	166	0.9	1.8
GG2	Aug.	6.6	6.7	1.5	2.0	2.8	1.2	0.38	0.13	193	268	0.8	2.1
	Oct.	6.6	6.7	1.6	1.5	2.8	1.6	0.15	0.07	368	274	0.9	1.5
JB	Aug.	6.2	6.6	2.6	1.2	0.9	2.0	0.30	0.28	90	172	1.1	1.7
	Oct.	6.9	7.1	1.3	2.2	2.3	2.6	0.21	0.17	355	289	1.6	2.7
Mean	Aug.	6.5	6.6	1.9	2.0	1.6	2.3	0.28	0.22	208	250	1.0	1.9
	Oct.	6.7	6.7	1.5	1.7	2.3	2.2	0.19	0.17	309	232	1.4	1.7
T-test													
Fertilizer (F)		NS		NS		NS		NS		NS		**	
Time (T)		NS		**		*		*		*		NS	
ANOVA													
Site (S)		NS		NS		NS		NS		NS		NS	
F * S		NS		NS		*		NS		NS		NS	
T * S		NS		*		NS		NS		NS		NS	
F * T * S		NS		NS		NS		NS		NS		NS	

[z]Fertilizer treated on May, July, August, and September in 2013.
[y]EC: electrical conductivity; OM: organic matter; T-N: total nitrogen.
[x]CB: Chungbuk; CN: Chungnam; GB: Gyeongbuk; GG1: Gyeonggi1; GG2: Gyeonggi2; JB: Jeonbuk.
[w]CF: chemical fertilizer; CLM: composted liquid manure.
NS, *, ** Nonsignificant or significant at *P*=0.05 and 0.01% level, respectively.

Results and Discussion

CLMs properties

The concentration of chemical constituents in CLMs showed a variation according to the production facilities and sampling timings in 2013 (Table 2). CLM at this study was moderately alkaline with average CLM pH 8.4 in 2013. The mean of EC and TDS of CLMs was 1.21 dS m^{-1} and 6,648 mg L^{-1}, respectively. The highest value of EC and TDS was observed at the CLM of Iksan facility in July, 2013, and it was 1.68 dS m^{-1} and 9,000 mg L^{-1}, respectively. The use of CLM for zoysiagrass maintenance is not considered to be a problem because zoysiagrass is reported as moderately salt-tolerant (6 to 8 dS m^{-1}) (Miyamoto, 2008).

The average total N in CLMs was 0.98 g L^{-1} and 1.22 g L^{-1} and each standard deviation was ±0.67 g L^{-1} and ±0.73 g L^{-1} in 2012 and 2013, respectively (Data in 2012 not shown). The CLM produced from Nonsan facility showed the largest total N content among all facilities. The mean of Av. P values within CLMs in the study was relatively low when compared with commercial organic fertilizer, which showed 10% of total N in CLM. In contrast, the Ex. K content in CLM averaged 200% higher than total N.

Soil properties

There was no significant difference in soil pH among fertilizer treatments and periods (Table 3). The average pH in plots was 6.7 and all pH value in the soil samples were higher than 6.2. The site GB's plot showed lower pH than other plots.

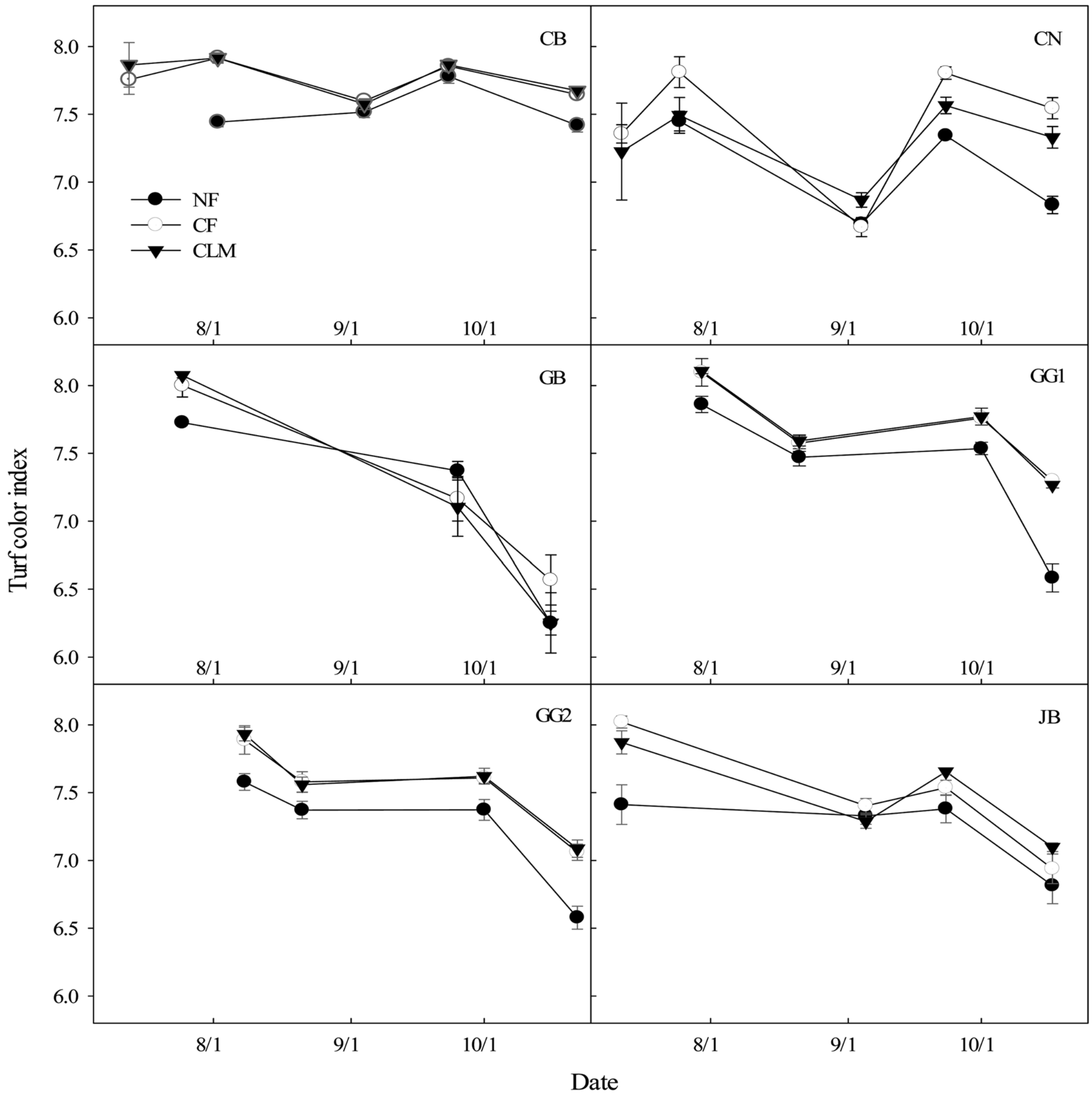

Fig. 1. Changes in turf color index of zoysiagrass as affected by fertilizer treatments at 6 experimental sites. NF: non-fertilization; CF: chemical fertilizer; CLM: composted liquid manure; CB: Chungbuk; CN: Chungnam; GB: Gyeongbuk; GG1: Gyeonggi1; GG2: Gyeonggi2; JB: Jeonbuk. Circles and vertical bars indicate the mean of 3 replicates and standard errors, respectively.

The soil EC showed significant difference according to the period. The soil EC's of CF and CLM treated plots on August showed lower values than those on October by 40% and 30%, respectively.

Organic matter content, total N, and Av. P also showed a significant difference in periods. Despite of no difference in the fertilizer treatment, CF treated plot on October showed 40% higher OM content than August. In contrast, the CLM plots showed 5% lower soil OM on October. These results could be attributed to the activity of microorganisms in manure. Boulter et al. (2000) reported that the composting process in the turf was mediated by microbial activity. Total N was decreased on October by 47% than August. In the case of Av. P content, CF treatment on October showed 49% higher Av. P, when compared with the CF treatment on August. On the contrary to this, CLM treatment on October showed 8% lower Av. P than CLM treatment on August. This results could be affected by relatively lower concentration of P within CLM compared with CF in this study. Soil Ex. K content only showed a statistically significant difference in the fertilizer treatment. Soil Ex. K content in the CLM treated plot was 46% higher than the CF treated plot. Like soil Av. P, increase of soil Ex. K content of CLM treated plots could be due to higher concentration of Ex. K within CLM than that of CF. Significant fertilizer×site and time×site interactions were observed on OM content and soil EC value, respectively. It is determined by the variability of the amount in accordance with the production time of CLM.

Turf color

Fig. 1 illustrates the change in turf color index associated with the different fertilization methods used at each experimental site. Application of CF or CLM resulted in a higher turf color index than non-treated turf in all experimental sites. However, the results showed no statistically significant difference between CF and CLM except for the site JB and CN, where CF increased the turf color index higher than CLM. These results correspond well with those reported in earlier experiments with zoysiagrass (Kang et al., 2010; Park et al., 2012). Likewise, when Kentucky bluegrass was treated with SCB liquid fertilizer supplemented with CF, the chlorophyll index increased by 24% compared to the control (Ham et al., 2011), which is consistent with the observation that the color of Kentucky bluegrass and creeping bentgrass increased with increasing nitrogen availability (Frank et al., 2006; Schlossberg and Schmidt, 2007). In the case of site JB and CN, the concentration of soil total N of plots treated with CF was higher than that of plots treated with CLM (Table 3), which probably affected turf color of site JB and CN.

The turf color index dramatically declined unexpectedly on late August and early September, 2013 at all experimental sites. We assumed that this was due to temporary nutrient deficiency as a result of the leaching of nutrients due to an abundant rainfall on July and August following fertilization on July, 2013. In the case of the site GB plot, there was no statistically significant difference between the treated plots and the control plot due to more than 35% large patch symptoms of the plots.

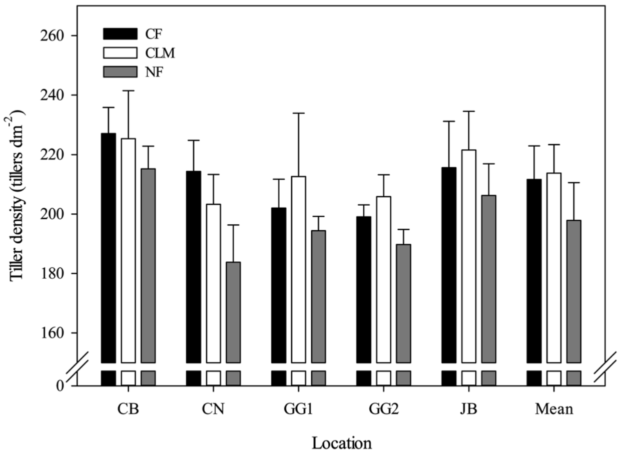

Fig. 2. Changes in tiller density of zoysiagrass as affected by fertilizer treatments at 5 experimental sites. CF: chemical fertilizer; CLM: composted liquid manure; NF: non-fertilization; CB: Chungbuk; CN: Chungnam; GG1: Gyeonggi1; GG2: Gyeonggi2; JB: Jeonbuk. Vertical bars indicate the standard errors.

Turf growth

Because of over 35% large patch disease incidence in site GB plots, data of turf density and dry weight from the site GB plot were excluded. Although there was not statistically significant difference, tiller density tended to maintain higher than that of non-fertilized control plot in all sites when turfgrass was fertilized with CF or CLM (Fig. 2). In case of Kentucky bluegrass, added nitrogen increased the number of large tillers (more than 1.5 cm in plant height) and produced similar increase in the number of initiated tillers due to reduced apical dominance by added nitrogen (Thompson and Clark, 1993). Especially, CLM application tended to increase tiller density by 9.4%, 8.5%, and 7.4% compared to no fertilizer application in site GG1, JB, and GG2 plots, respectively. Tiller densities of CLM treated plot were 5.3%, 3.4%, and 2.8% higher than those of CF treated plot except the site CN Application of liquid pig manure to winter forage crops (whole-crop-barley, rye, triticale, Italian ryegrass) resulted in higher plant lengths and tillers than CF (Cho et al., 2013). In addition, the shoot density of SCB treated plots was significantly higher than non-fertilized control plot of zoysiagrass (Park et al., 2012).

Like tiller density, though the difference was not shown, turf plots fertilized with CF and CLM showed higher dry weight

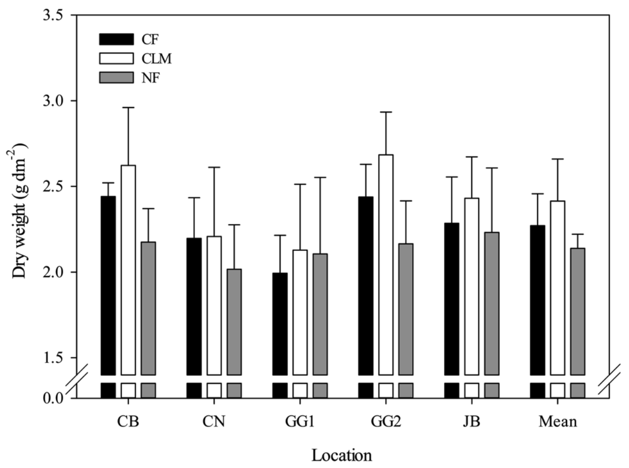

Fig. 3. Changes in dry weight of zoysiagrass as affected by fertilizer treatments at 5 experimental sites. CF: chemical fertilizer; CLM: composted liquid manure; NF: non-fertilization; CB: Chungbuk; CN: Chungnam; GG1: Gyeonggi1; GG2: Gyeonggi2; JB: Jeonbuk. Vertical bars indicate standard errors.

than non-fertilized control plot in all sites except GG1 site (Fig. 3). In the case of GG1 site, the non-fertilized plot showed an increase in dry weight compared with the CF treated plot, which may be an experimental mistake such as impurities occurrence. The CLM treatment resulted in 6.3% higher dry weight than CF treatment. In the case of Ham et al. (2010) showed that treatment with SCB liquid fertilizer (2 L m^{-2}) + 50% CF increased the dry weight of creeping bentgrass by 48% compared to non-fertilized and by 26% compared to CF-fertilized turf, respectively.

In general, CLM treated plot had similar turf color, density, and dry weight compared to CF treated plot. Therefore CLM could be used to manage turfgrass as a substitute for CF.

Conclusions

Interest in using CLM in the turfgrass management increased with the effectuation of London protocol from 2012 (Park et al., 2012). From the results, the mean value of total N, available P, and exchangeable K in CLM was 1.2, 0.12, and 2.1 g L^{-1}, respectively. CLM treated plots exhibited improvement in turf color and tiller density during the experiment period without fertilizer injury compared to non-fertilized plots. Although there was no significant difference, these effects for turf quality could be attributed to the differences in soil chemical properties affected by CLM applications. Because of relatively lower concentration of P within CLM, soil P content of CLM treated plot decreased, which would reduce the concern about environmental problems such as phosphorus leaching and following eutrophication. As a results, we recommend more than four times CLM applications of 3 L·m^{-2} annually (total 12 L·m^{-1} per year) on zoysiagrass management. However, the long-term effects of CLM on soil chemical properties in zoysiagrass maintenance should be investigated, especially on K concentration. The effects of the different CLMs varied due to different fertilizer constituents and the degree of composting in accordance with production length and location of treatment facilities. Therefore, there is a need to establish a system to produce CLM with a uniform nutrient composition and the degree of composting in order to encourage utilization of CLM liquid fertilizer in turfgrass.

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