Kor. J. Hort. Sci. Technol. 30(6):635-641, 2012 DOI http://dx.doi.org/10.7235/hort.2012.12099

Optimum Application Amount, Timing, and Frequency of Slurry Composted and Biofiltered Liquid Fertilizer for *Zoysia japonica* 'Millock'

Suejin Park[1], Seung Youn Lee[1], Ju Hyun Ryu[1], Hyun Hwan Jung[1,2], and Ki Sun Kim[1,2]*

[1]*Department of Plant Science, Seoul National University, Seoul 151-921, Korea*
[2]*Research Institute for Agriculture and Life Science, Seoul National University, Seoul 151-921, Korea*

Abstract. In Korea, slurry composted and biofiltered (SCB) liquid fertilizer is produced through the composting and biofiltering of animal waste. An appropriate guidelines involving proper treatment of SCB liquid fertilizer on turfgrass should be considered. An experiment was conducted to determine the optimum application amount, timing, and frequency of SCB liquid fertilizer for *Zoysia japonica* 'Millock'. The SCB liquid fertilizer was applied in low, medium, and high amount (N at 15, 25, and 40 $g \cdot m^{-2}$ per year in 2010, and 10, 20, and 40 $g \cdot m^{-2}$ per year in 2011, respectively) and treated during the growing season or dormancy period. During the growing season, SCB liquid fertilizer was applied twice or four times. The greatest improvement in turf quality for both years was in SCB plots applied four times with N at 40 $g \cdot m^{-2}$ per year during the growing season (SH4). This treatment exhibited turf color retention in the fall, and enhanced clipping yield during the growing and fall seasons. SCB plots with four times during the growing season (SL4, SM4, and SH4) exhibited higher shoot density relative to the same amount of other SCB treatments. Plots treated during the dormancy period also showed a high turf color index during the next growing season in 2011. The results indicate that SCB with high amount up to N at 40 $g \cdot m^{-2}$ per year applied four times during the growing season and dormant application produced high turf quality and growth, and could be recommended as an optimum application guide.

***Additional key words*:** clipping yield, fall color retention, shoot density, turf color index

Introduction

In many countries, the increasing quantity of animal waste from livestock operations puts pressure on waste disposal services. The potential impact of livestock production on environmental quality has become a matter of nationwide concern (Vukina, 2003). Animal wastes contain excess nitrates, phosphates, salts, undesirable microorganisms, pathogens, and produce greenhouse gases (Eghball and Power, 1999). Without proper disposal treatment they can pollute the soil, water, and air. However, animal waste contains high levels of organic matter and a considerable amount of essential nutrients for plant growth (Cheng et al., 2007). Nitrogen in animal waste could be applied as a replacement for chemical fertilizer in agriculture production (Smith and Wheeler, 1979). Using untreated animal waste produces odors and nutrient unevenness for agriculture source, and those disadvantages have been obstacles to use them as a fertilizer (Misselbrook et al., 1997).

Animal wastes can now be treated using biological and physico-chemical method (Kushwaha et al., 2010). In Korea, slurry composted and biofiltered (SCB) liquid fertilizer is produced by a composting and biofiltering process, and this process yields an odorless, homogeneous, pure, low concentration, humus-like, and biologically stable organic material (Ham et al., 2009). SCB liquid fertilizer has been applied as a partial replacement for chemical fertilizer on many plants including red pepper, tomato, forage crop, cucumber, yellow poplar, and pine tree (Ham et al., 2009; Jo et al., 2010; Kim et al., 2011; Lim et al., 2008; Park et al., 2011; Seo et al., 2010). Although SCB liquid fertilizer could be used on many crops including rice, fruits, and vegetables, the mass

***Corresponding author:** kisun@snu.ac.kr

※ Received 24 May 2012; Revised 6 September 2012; Accepted 6 September 2012. This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. 006635)" Rural Development Administration, Republic of Korea.

production of SCB liquid fertilizer could not be consumed by these industries. Areas with turf, such as golf courses, are enough space to apply a large amount of SCB liquid fertilizer.

Numerous studies have been conducted to determine the effects of composted manure application on turfgrass growth as an alternative to chemical fertilizer (Gaudreau et al., 2002; Go et al., 2006; McLaughlin et al., 2004). Ham et al. (2009) and Kang et al. (2010) evaluated the effectiveness of SCB liquid fertilizer mixed with chemical fertilizer on bentgrass and zoysiagrass. They found that a mixed application of SCB liquid fertilizer and chemical fertilizer led to high turf growth and quality. In order to increase the consumption of SCB liquid fertilizer in turfgrass managements, new and convenient fertilization programs with utilizing SCB liquid fertilizer should be considered. Because the SCB process yields liquid fertilizer with low nitrogen concentration, proper application would be different from that of granular fertilizer. However, little research has been conducted to assess the appropriate application of SCB liquid fertilizer. The objectives of this study were to determine the optimum application amount, timing, and frequency of SCB liquid fertilizer for *Z. japonica* 'Millock' and then to recommend a practical guide for the application of SCB liquid fertilizer in turf grass management.

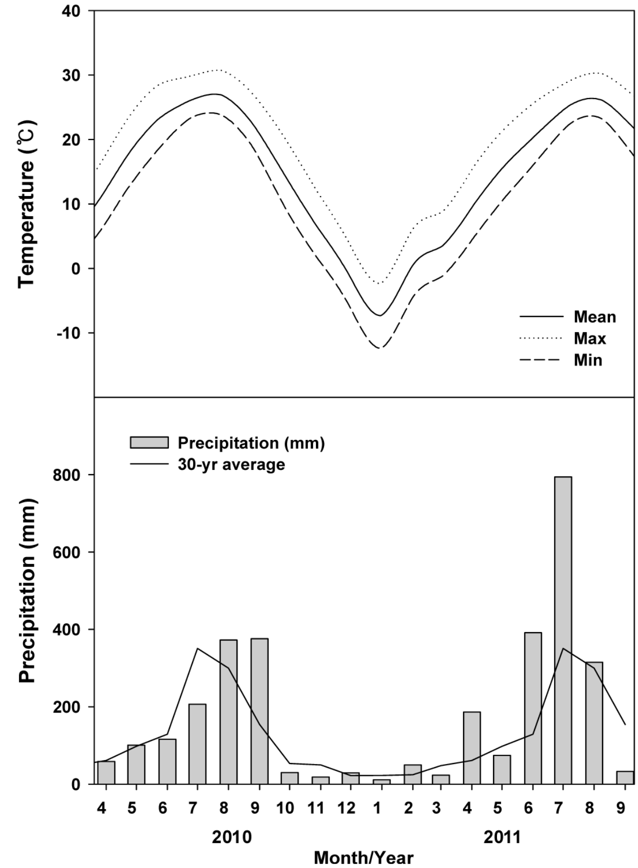

Fig. 1. Climate conditions at the experimental plot site.

Table 1. Chemical constituents of SCB solution used in the field study.

Nutrient	The type of SCB solution (mg·L^{-1})		
	SCB1^z	SCB2	SCB3
T-N	282.3	131.8	1129.7
P	170.3	54.2	152.0
K	1100.7	2126.0	1154.4
Ca	174.3	156.5	207.6
Mg	203.6	131.0	181.6
Fe	2.6	2.5	1.4

^{z}SCB1, SCB2, and SCB3 were provided by National Institute of Animal Science on July 6, August 13, and October 11, 2010, respectively.

Materials and Methods

Experimental Site and Culture Condition

A field experiment was conducted at the Experimental Farm of the College of Agriculture and Life Sciences, Seoul National University (Suwon, Korea). Experimental plots were established on April 30, 2010 and sodded with *Z. japonica* 'Millock' purchased from Lgreen (Gwacheon, Korea). Individual sub-plots measured 1.5 by 1.5 m. The ambient air temperature and the amount of precipitation were received from Suwon Meteorological Station located near to the field study plot (Fig. 1). The plots were watered as necessary to prevent moisture stress.

Analysis of SCB Liquid Fertilizer

SCB liquid fertilizer was produced at the National Institute of Animal Science (Suwon, Korea). The chemical characteristics of SCB liquid fertilizer are presented in Table 1. All analyses were performed at the National Instrumentation Center for Environmental Management, Seoul National University (Seoul, Korea). Total and inorganic nitrogen was measured by the Kjeldahl method (Bremmer, 1996; Mulvaney, 1996). All other nutrients were quantified using inductively coupled plasma spectrophotometry after acid digestion.

Fertilizer Treatments

SCB liquid fertilizer was applied at either a low (L), medium (M), and high (H) amount (N at 15, 25, and 40 g·m^{-2} per year in 2010, and 10, 20, and 40 g·m^{-2} per year in 2011, respectively). Application timing treatments consisted of growing season and dormancy period. During the growing season, SCB liquid fertilizer was applied twice and four times. The chemical fertilizer used in this study was a

Table 2. SCB solution and chemical fertilizer application schedules for the field study in 2010 and 2011.

Treatment	Fertilizer amount (N at g·m^{-2})											
	2010					2011						
	July 26	Aug. 31	Sep. 24	Oct. 23	Total	Mar. 4	Apr. 1	May 6	June 10	July 21	Aug. 26	Total
NF[z]	-	-	-	-	0	-	-	-	-	-	-	0
CL2	5.0	-	10.0	-	15	-	-	5.0	-	5.0	-	10
SL2	14.0	-	1.0	-	15	-	-	5.0	-	5.0	-	10
SL4	5.6	2.4	3.5	3.5	15	-	-	2.5	2.5	2.5	2.5	10
SLD	14.0	-	-	1.0	15	5.0	5.0	-	-	-	-	10
SM2	22.4	-	2.6	-	25	-	-	10.0	-	10.0	-	20
SM4	11.2	3.4	5.2	5.2	25	-	-	5.0	5.0	5.0	5.0	20
SMD	22.4	-	-	2.6	25	10.0	10.0	-	-	-	-	20
SH2	22.4	-	17.6	-	40	-	-	20.0	-	20.0	-	40
SH4	22.4	4.4	6.6	6.6	40	-	-	10.0	10.0	10.0	10.0	40
SHD	22.4	-	-	17.6	40	20.0	20.0	-	-	-	-	40
	SCB1[y]	SCB2	SCB2	SCB3		SCB3	SCB3	SCB3	SCB3	SCB3	SCB3	

[z]NF denotes no fertilizer. C or S indicates chemical or SCB fertilizers. The letters L, M, and H indicate low, medium, and high application amounts, respectively, and D indicates application during the dormancy period. Numbers indicate the number of treatments over the growing season.

[y]For the information about SCB solution used in each time of fertilizer application, refer to Table 1.

commercial granular fertilizer (10N-6P-13K, KG Chemical, Bucheon, Korea).

The treatments included no fertilizer (NF), chemical fertilizer with a low amount applied twice during the growing season (CL2), SCB in low, medium, and high amounts applied either twice or four times during the growing season (SL2, SM2, SH2, and SL4, SM4, and SH4, respectively). SCB was also applied in low, medium, and high amounts during the dormancy period (SLD, SMD, and SHD, respectively). Since SCB liquid fertilizer was available late in 2010, SLD, SMD, and SHD plots were treated with SCB liquid fertilizer on July 26. The dates of the treatments are shown in Table 2.

Measurements

Turf quality and fall color retention were obtained as turf color index measured using a turf color meter (TCM 500, Spectrum Technologies, Inc., USA). Experimental plots were mowed at a height of 21 mm. Clippings were harvested on August 27 and September 17 in 2010, and July 21 and August 19 in 2011. Clippings were dried at 80℃ for 72 h in an oven and weighted. At the end of the experiment each year, plant samples were collected by using a 10-cm-diameter hall cutter. Shoot density and fresh weight were measured, and samples were oven-dried at 80℃ for 72 h to measure dry weight.

Experimental Design and Data Analysis

The experiment was conducted as a completely randomized design with four replicates. SAS version 9.2 (SAS Institute Inc., Cary, NC, USA) was used to perform analysis of variance (ANOVA) and general linear models (GLM). Differences among the treatment means were assessed by Fisher's least significant difference test at $P < 0.05$. Orthogonal contrasts were used to make preplanned comparisons among means for each treatment group.

Results and Discussion

Turf Quality

Fertilization with chemical or SCB fertilizers produced a higher turf color index than unfertilized turf throughout the course of the experimental period (Figs. 2 and 3). The turf color of the CL2 plot was lower than those of all SCB plots on August 18, 2010 (Fig. 2A). Turf treated with SM4 and SH4 had turf color index that were 0.31 and 0.36 higher than that of CL2 on September 17, 2010 respectively (Fig. 2B). SCB plots treated with N at 40 g·m^{-2} per year (SH2, SH4, and SHD) had a significantly higher turf color index on June 10, 2011 (Fig. 3A). Although SLD, SMD, and SHD were applied only during the dormancy period, those plots maintained a high turf color index during the next growing season in 2011 (Figs. 3A and 3B). The results suggested that SCB liquid fertilizer can produce turf quality that is equivalent to that of low amounts of chemical fertilizer. Previous studies reported that turf quality is associated with the nitrogen content of fertilizer (Bilgili and Acikgoz, 2005;

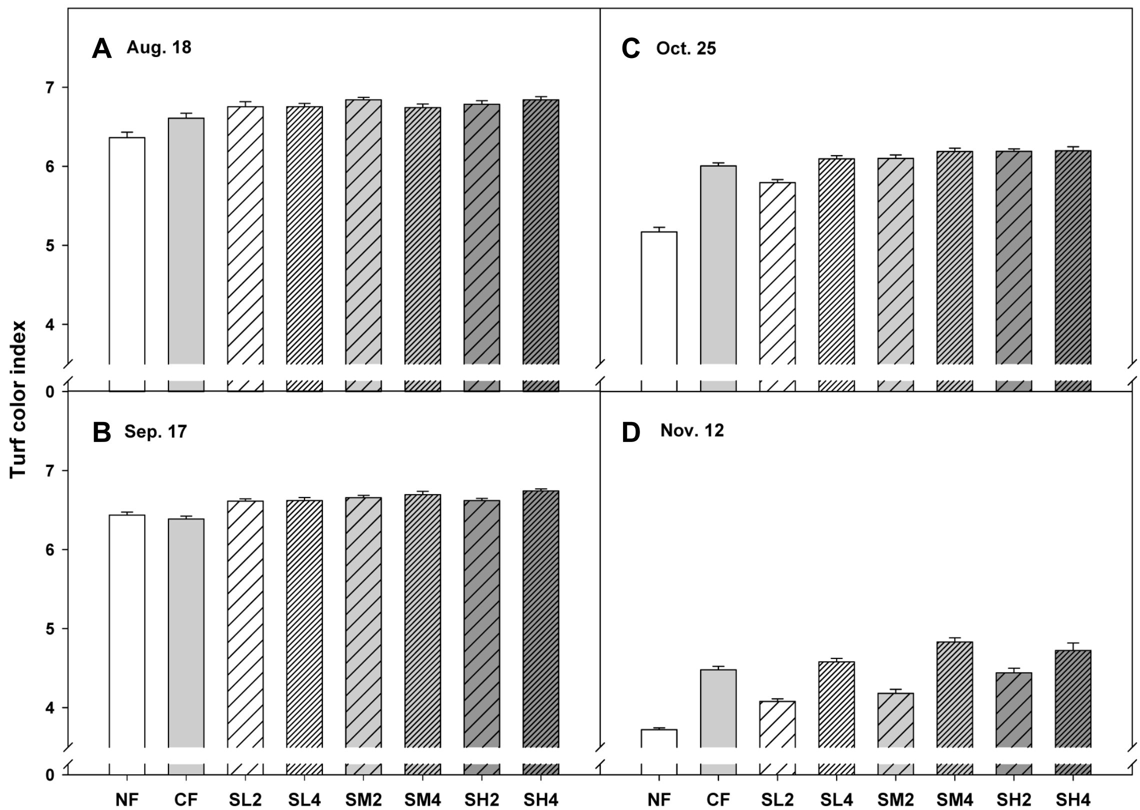

Fig. 2. Effect of the amount, timing, and frequency of SCB liquid fertilizer application on the turf color index of *Z. japonica* in 2010. Vertical bars are standard errors of the means (n = 4). For fertilizer treatment details, refer to Table 2.

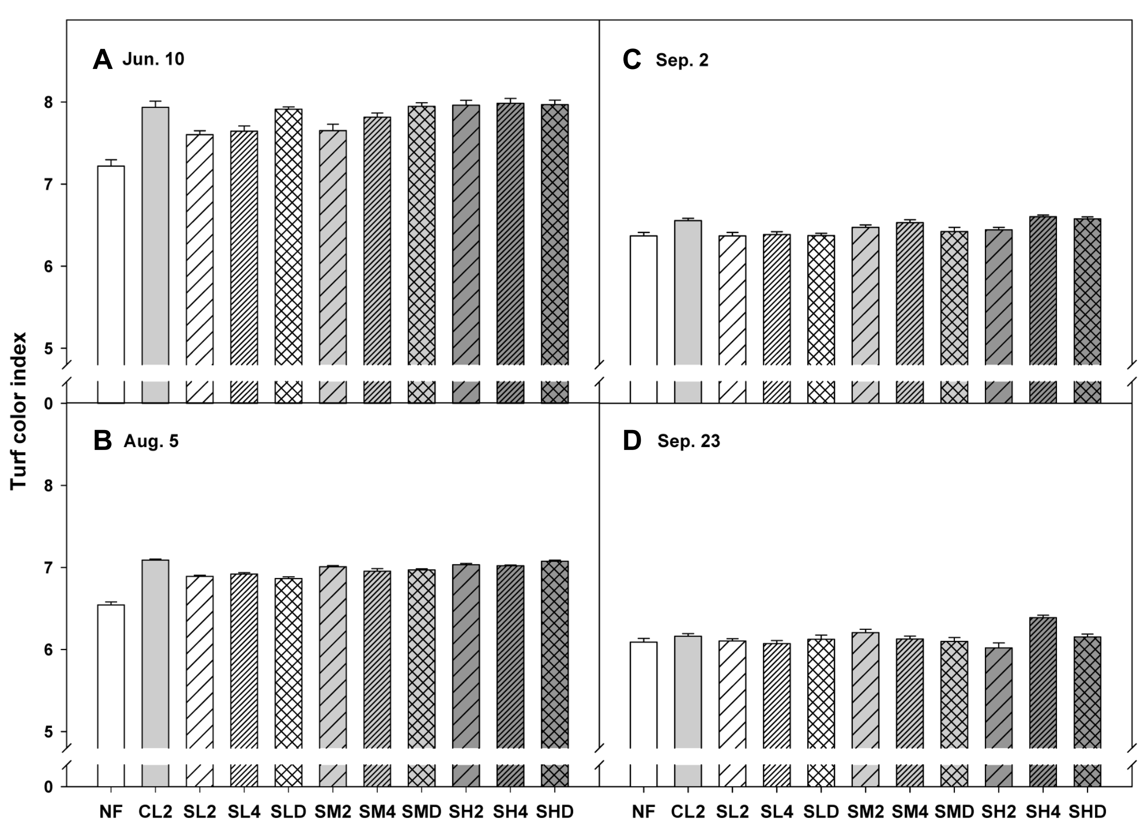

Fig. 3. Effect of the amount, timing, and frequency of SCB liquid fertilizer application on the turf color index of *Z. japonica* in 2011. Vertical bars are standard errors of the means (n = 4). For fertilizer treatment details, refer to Table 2.

Wehner et al., 1988). The color of Kentucky bluegrass and creeping bentgrass increased with an increase in available nitrogen (Frank et al., 2006; Schlossberg and Schmidt, 2007). Kang et al. (2010) showed that SCB liquid fertilizer treatment in higher quantities yielded higher turf quality of zoysiagrass. Contrary to 2010, CL2 plots in the present study exhibited higher turf color index than SCB plots in 2011. These results may be due to the intense precipitation in 2011. The 2011 growing season had a total of 1,976 mm of precipitation (Fig. 1). Specifically, the precipitation in July 2011 was 443.2 mm higher than normal. It is assumed that leaching of nutrients was more pronounced for SCB fertilizer than for the chemical granular fertilizer because liquid fertilizers generally leach more quickly.

Fall Color Retention

SL4, SM4, and SH4 significantly improved turf color retention from October to November in 2010 (Figs. 2C and 2D). They resulted in higher fall color retention by 0.86, 1.11, and 1.00, respectively, than that of NF on November 12, 2010 (Fig. 2D). The fall color retention in plots treated with SH4 was 0.30 higher than that of NF on September 23, 2011 (Fig. 3D). Late nitrogen fertilization often decreases the low temperature tolerance of turf (Wilkinson and Duff, 1972). However, there was no visible sign of injury for any treatment in the experimental period. SH4 enhanced the fall color retention of *Z. japonica* both in 2010 and 2011. Oral and Acikgoz (2001) reported that split applications yielded the highest overall turf quality and longer duration than heavy applications.

Clipping Yield

SCB plots produced higher clipping yield than CL2 in 2010 (Figs. 4A and 4B). SH4 maintained the highest clipping yield on September 17, 2010 (Fig. 4B). SL4, SM4, and SH4 resulted in high clipping yield, and SCB liquid fertilizer with N at 40 $g \cdot m^{-2}$ led to high clipping yield on July 21, 2011 (Fig. 4C). These results indicate that the SH4 treatment enhanced clipping yield during the growing and fall seasons. Increasing nitrogen significantly increased clipping yield in turf mixtures (Bilgili and Acikgoz, 2005). However, a greater frequency of application resulted in a more uniform clipping yield and reduced the total clipping weight (Bilgili and Acikgoz, 2005). SHD maintained a high clipping yield until June 21, 2011 (Fig. 4C), but SLD resulted in a lower clipping yield than SMD and SHD. SCB liquid fertilizer applied during the dormancy period produced leaf growth, but SLD application was not sufficient to increase turf growth.

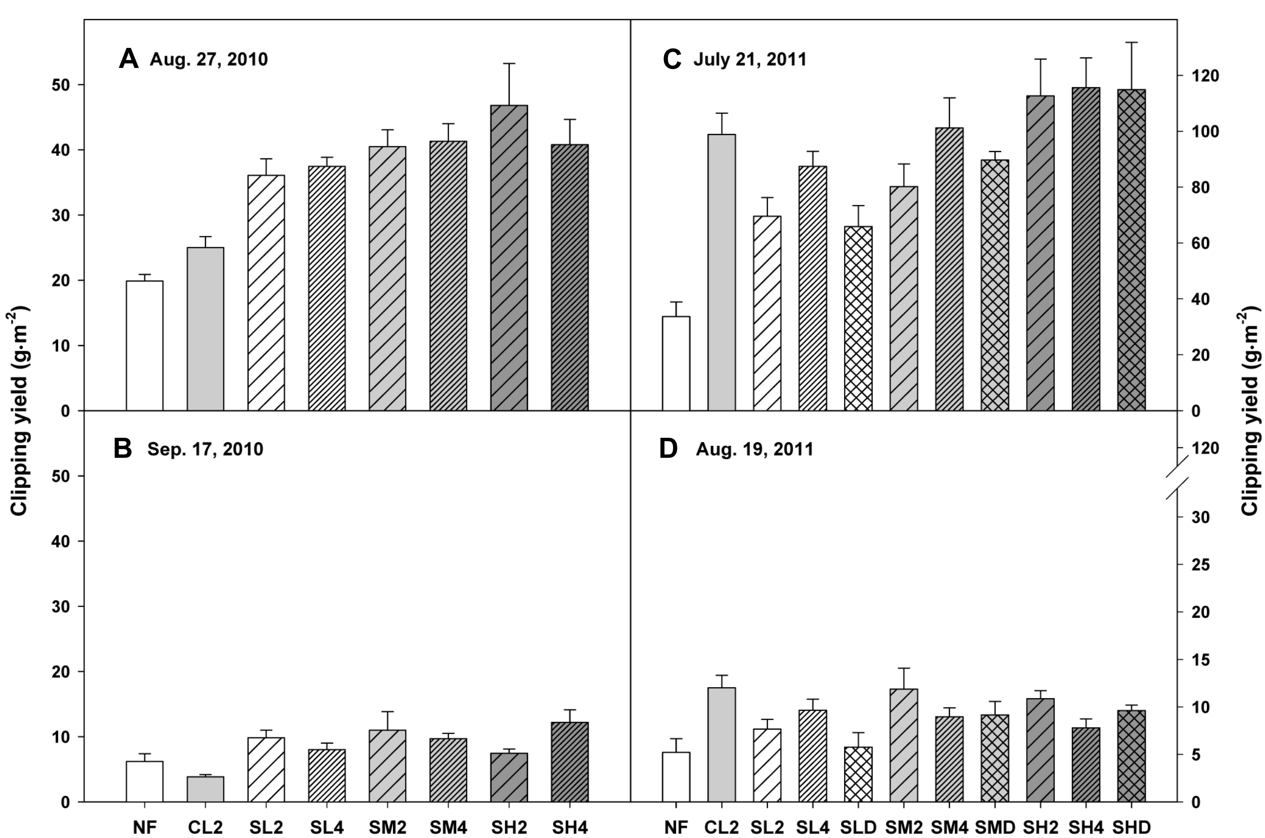

Fig. 4. Effect of the amount, timing, and frequency of SCB liquid fertilizer application on the clipping yield of *Z. japonica* in 2010 and 2011. Vertical bars are standard errors of the means (n = 4). For fertilizer treatment details, refer to Table 2.

Compared with clipping yield in August 2010, fewer clippings were collected in August 2011 (Figs. 4A and 4D). This result was probably attributable to above normal precipitation in 2011 (Fig. 1).

Shoot Density

Significant differences in shoot density were observed among treatments (Table 3), but there were no differences in fresh and dry weight (data not shown). Shoot density from fertilizer treatments was significantly greater than NF in 2010 (Fig. 5A). SCB treatments resulted in higher shoot density than CL2, with no differences among SCB treatments (Fig. 5A and Table 3). The difference in shoot density was not statistically significant among SCB treatments. However, SL4, SM4, and SH4 increased shoot density compared to the same amounts of the other SCB treatments (data not shown). No statistically significant differences in shoot density were observed among treatments in 2011 (Table 3). All fertilizer treatments including CL2 and SCB treatments were greater than NF for shoot density (Fig. 5B). Although there was no significant difference in shoot density among fertilizer treatments, SCB plots with four times (SL4, SM4, and SH4) and those applied with medium and high amounts of SCB (SM2, SH2) had similar shoot densities compared to CL2 (data not shown). Moore et al. (1996) found no differences among nitrogen treatments in shoot density, and Hanson and Juska (1961) reported high tiller development in a fall nitrogen fertilization program for Kentucky bluegrass. In the present study, however, SL4, SM4, and SH4 produced a greater shoot density than other SCB treatments. Oral and Acikgoz (2001) found that frequent and light applications were more effective than infrequent and heavy applications.

Table 3. Summary of ANOVA and GLM results for shoot density of *Z. japonica* in 2010 and 2011.

Source of variation	2010	2011
Treatment	*	NS
NF vs. other treatments	**	*
CL2 vs. SCB	*	NS
SCB	NS	NS

NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01, respectively.

Conclusion

SCB plots applied four times with N at 40 $g \cdot m^{-2}$ per year (SH4) had the greatest improvement in turf quality, color retention, clipping yield, and shoot density for both years. Plots treated during the dormancy period also showed a high turf color index during the next growing season in 2011. Our data suggests that split application of a high amount of SCB liquid fertilizer could serve as a substitute for chemical fertilizer, and dormant application could improve turf quality during the next growing season. Consequently, utilization of SCB liquid fertilizer with high amount for turfgrass could not only enhance turf growth, but also consume the mass production of SCB liquid fertilizer. During the two years of this study, we observed no symptoms of phosphorus deficiency. However, if SCB liquid fertilizer were applied over an extended time period, supplemental phosphorus should be considered due to the lack of phosphorus in SCB liquid fertilizer (Kang et al., 2010). Furthermore, the constituents of SCB liquid fertilizer vary based on when and where the fertilizer is produced. To promote consumption of SCB liquid fertilizer, it is essential to control nutrient

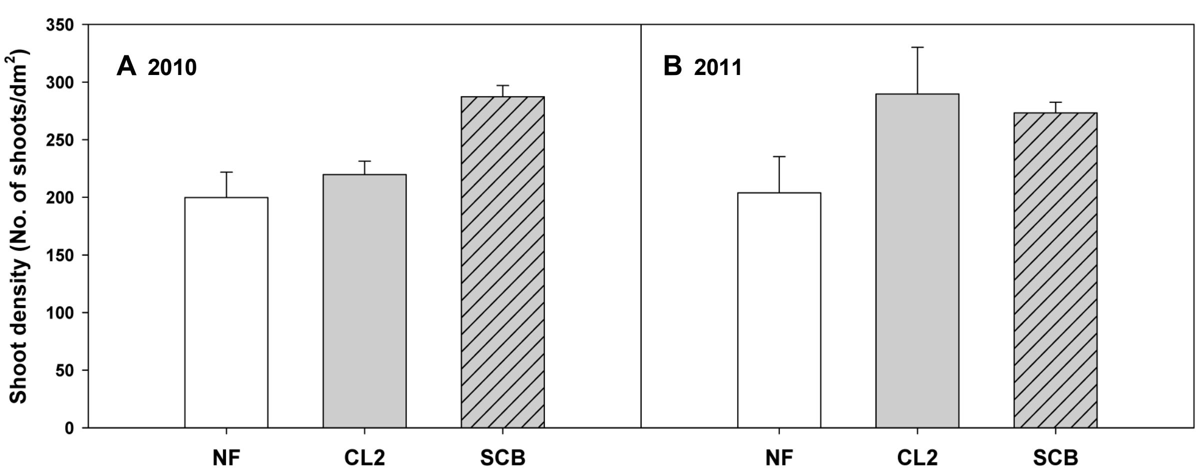

Fig. 5. Effect of fertilizer treatments on the shoot density of *Z. japonica*. Means of SCB were determined across SCB treatments. Vertical bars are standard errors of the means (n = 4, 4, and 36 respectively for NF, CL2, and SCB). NF, no fertilizer; CL2, chemical fertilizer with a low amount applied twice during the growing season; SCB, SCB liquid fertilizer treatments.

constituent uniformly. Although application of SCB liquid fertilizer with high amount may cause nutrient leaching and ground water contamination, Kang et al. (2010) documented that SCB liquid fertilizer treatment with double amount of chemical fertilizer showed less nutrient leaching than chemical fertilizer. Nutrient leaching might be low in golf courses because nutrient leaching is negatively correlated with a well-developed root system of turfgrass (Bowman and Rufty, 2002). For example, Kim et al. (2012) reported SCB liquid fertilizer application rarely contaminated the pond in golf course. In practical applications, however, it may be necessary to conduct a long term effect of SCB liquid fertilizer application on turfgrass and nutrient leaching.

Literature Cited

Bilgili, U. and E. Acikgoz. 2005. Year-round nitrogen fertilization effects on growth and quality of sports turf mixtures. J. Plant Nutr. 28:299-307.

Bowman, D.C. and C.T. Rufty. 2002. Fate and transport of nitrogen applied to six warm-season turfgrasses. Crop Sci. 42:833-841.

Bremmer, J.M. 1996. Nitrogen-total, p. 1085-1121. In: J.M. Bartels and D.L. Sparks (eds.). Methods of soil analysis. Part 3-Chemical methods, Soil Science Society of America, Madison, W.I.

Cheng, H., W. Xu, J. Liu, Q. Zhao, Y. He, and G. Chen. 2007. Application of composted sewage sludge (CSS) as a soil amendment for turfgrass growth. Ecol. Eng. 29:96-104.

Eghball, B. and J.F. Power. 1999. Composted and noncomposted manure application to conventional and no-tillage systems: Corn yield and nitrogen uptake. Agron. J. 91:819-825.

Frank, K.W.O.R., K.M. Crum, J.R. Calhoun, and N. Ronald. 2006. The fate of nitrogen applied to a mature Kentucky bluegrass turf. Crop Sci. 46:209-215.

Gaudreau, J.E., D.M. White, R.H. Provin, and T.L. Munster. 2002. Response of turf and quality of water runoff to manure and fertilizer. J. Environ. Qual. 31:1316-1322.

Go, S.K., H.S. Tae, and C.H. Pyu. 2006. Effect of animal organic soil amendment on growth of Korean lawngrass and Kentucky bluegrass. Kor. J. Turfgrass Sci. 20:33-40.

Ham, S.K., Y.S. Kim, T.S. Kim, K.S. Kim, and C.H. Park. 2009. The effect of SCB (slurry compostion and biofilter) liquid fertilizer on growth of creeping bentgrasss. Kor. J. Turfgrass Sci. 23:91-100.

Hanson, A.A. and F.V. Juska. 1961. Winter root activity in Kentucky bluegrass (*Poa pratensh* L.). Agron. J. 53:372-374.

Jo, N.C., J.S. Shin, S.H. Kim, S.H. Yoon, S. Hwangbo, M.W. Jung, K.D. Lee, W.H. Kim, S. Seo, J.G. Kim, C.E. Song, and K.C. Choi. 2010. Study on summer forage crop cultivation using SCB (slurry composting-biofilteration) liquid fertilizer on reclaimed land. J. Kor. Grassl. Forage Sci. 30:121-126.

Kang, B.K., H.H. Jung, and K.S. Kim. 2010. Effect of slurry composted and biofiltered solution as an organic fertilizer on the growth of zoysiagrass. Hort. Environ. Biotechnol. 51:507-512.

Kim, H.Y., K.S. Gwak, H.Y. Kim, K.O. Ryu, P.G. Kim, D.H. Cho, J.Y. Choi, and I.G. Choi. 2011. Effect of treatment amounts of slurry composting and biofitration liquid fertilizer on growth characteristics and bioethanol production of yellow poplar. Kor. Soc. Wood Sci. Tech. 39:459-468.

Kim, Y.S., S.K. Ham, and H.J. Lim. 2012. Monitoring of soil chemical properties and pond water quality in golf courses after application of SCB liquid fertilizer. Asian J. Turfgrass Sci. 26:44-53.

Kushwaha, J.P., V.C. Srivastava, and I.D. Mall. 2010. Treatment of dairy wastewater by inorganic coagulants: Parametric and disposal studies. Water Res. 44:5867-5874.

Lim, T.J., S.D. Hong, S.H. Kim, and J.M. Park. 2008. Evaluation of yield and quality from red pepper for application rates of pig slurry composting biofiltration. Kor. J. Environ. Agr. 27:171-177.

McLaughlin, M.R., T.E. Fairbrother, and D.E. Rowe. 2004. Nutrient uptake by warm-season perennial grasses in a swine effluent spray field. Agron. J. 96:484-493.

Misselbrook, T.H., P.J. Hobbs, and K.C. Persaud. 1997. Use of an electronic nose to measure odour concentration following application of cattle slurry to grassland. J. Agr. Eng. Res. 66:213-220.

Moore, R.W., N.E. Christians, and M.L. Agnew. 1996. Response of three Kentucky bluegrass cultivars to sprayable nitrogen fertilizer programs. Crop Sci. 36:1296-1301.

Mulvaney, R.L. 1996. Nitrogen-inorganic forms, p. 1123-1184. In: J.M. Bartels and D.L. Sparks (eds.). Methods of soil analysis. Part 3-Chemical methods, Soil Science Society of America, Madison, W.I.

Oral, N. and E. Acikgoz. 2001. Effects of nitrogen application timing on growth and quality of a turfgrass mixture. J. Plant Nutr. 24:101-109.

Park, J.M., T.J. Lim, S.E. Lee, and I.B. Lee. 2011. Effect of pig slurry fertigation on soil chemical properties and growth and development of cucumber (*Cucumis sativus* L.). Kor. J. Soil Sci. Fert. 44:194-199.

Schlossberg, M.J. and J.P. Schmidt. 2007. Influence of nitrogen rate and form on quality of putting greens cohabited by creeping bentgrass and annual bluegrass. Agron. J. 99:99-106.

Seo, Y.H., B.O. Cho, H.K. Choi, A.S. Kang, B.C. Jeong, and Y.S. Jung. 2010. Impact of continuous application of swine slurry on changes in soil properties and yields of tomatoes and cucumbers in a greenhouse. Kor. J. Soil Sci. Fert. 43:446-452.

Smith, L.W. and W.E. Wheeler. 1979. Nutritional and economic value of animal excreta. J. Anim. Sci. 48:144-156.

Vukina, T. 2003. The relationship between contracting and livestock waste pollution. Rev. Agr. Econ. 25:66-88.

Wehner, D.J., J.E. Haley, and D.L. Martin. 1988. Late fall fertilization of Kentucky bluegrass. Agron. J. 80:466-471.

Wilkinson, J.F. and D.T. Duff. 1972. Effects of fall fertilization on cold resistance, color, and growth of Kentucky bluegrass. Agron. J. 64:345-348.