Weed Turf. Sci. 10(2):155-162
https://doi.org/10.5660/WTS.2021.10.2.155

Print ISSN 2287-7924
Online ISSN 2288-3312

RESEARCH ARTICLE

Nitrogen Efficiency and Shoot Growth of Creeping Bentgrass after Application of Slow Release Nitrogen Fertilizer

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Abstract

This study was conducted to evaluate effects of two slow release nitrogen (N) fertilizers (SRF) blending isobutylidene diurea (IBDU) or methylene urea (MU) on growth, quality and N uptake of creeping bentgrass. Treatments were designed as follow; non-fertilizer (NF), control fertilizer (CF), SRF-1 (IBDU 10%, MU 23%), and SRF-2 (MU 33%). As applied SRF, visual quality, shoot length, clipping yield, top-root (T/R) ratio and N uptake of creeping bentgrass was increased than that of CF. Amount of N uptake was positively correlated to visual quality, shoot length, total chlorophyll content, clipping yield, and dry weight of shoot and root (P<0.01). N efficiency of SRF-1 and SRF-2 increased by 39% and 61% than that of CF. These results demonstrated that application of slow release nitrogen fertilizer improved turfgrass quality and shoot growth of creeping bentgrass by prompting N uptake.

Keywords: Creeping bentgrass, N efficiency, N uptake, Slow release nitrogen fertilizer (SRF)

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Received: June 07, 2021

Revised: June 25, 2021

Accepted: June 27, 2021

Introduction

Nitrogen (N) is very important element organizing plant tissue with phosphorous (P) and potassium (K), and driven uptake of P and K into turfgrass from soil (Kussow et al., 2012). N in turfgrass management was supplied by applying N fertilizers, that divided straight fertilizer (SF) and slow release fertilizer (SRF). Generally, SF containing N was urea, ammonium sulfate, calcium cyanide etc., and very soluble in water and easy to leaching in root zone of sand green (Lee et al., 2005). SRF was compound bonded hydrocarbon such as isobutylidene diurea (IBDU), crotonylidene diurea (CDU), methylene urea (MU) and urea formaldehydes (UF), and slowly released into root zone by decomposing with water and microorganisms (Lee et al., 2001).

In sand green of golf course, soil amendments blending sand were matched on United States Golf Association (USGA) guideline, in order to improve soil physicochemical properties, because permeating water and flowing air was high, but cation exchangeable capacity low (Kim et al., 2010). In turfgrass management, N of SF had a short fertilized interval time and was increased leaching (Guillard and Kopp, 2004). However, N of SRF in root zone was increased fertilizer efficiency, available N content, and reduced N leachates and fertilizing efforts (Guillard and Kopp, 2004; Kim et al., 2009a).

Park and Choy (1986) reported that SRF applying in the sandy soil progressed the growth of shoot and root in radish (*Raphanus raphanistrum*). Also, it was improved N uptake in rice (*Oryza sartiva* L.) by increasing content of available N such as ammonium and nitrate, that were absorbed N types from soil into plant (Cheong, 1996; Lee et al., 2005). Lee et al. (2001) reported that when SRF was fertilized in *Allium cepa* L., its production was increased by 17% and decreased sprouting rate and rots during its storage periods. Kim et al. (2009a, b) demonstrated that applying IBDU or MU were progressed growth and quality by prompting N uptake of cool season turfgrass and by increasing available N in root zone of sand green. We get to know that SRFs have different properties such as release rate in soil, fertilizer efficiency and plant growth by their formulation type (Lee et al., 2001). If respective N source of SRF was blended in formulation, SRF could improve a fertilizer efficiency.

The aims of this experiment is that influence of application of two SRFs blending IBDU, or MU on growth and quality of creeping bentgras (*Agrostis palustris* H.).

Materials and Methods

Experiment materials

This study was conducted in green house of Chungnam National University located on Daejeon during six months from October 2015 to March 2016. Creeping bentgrass (*A. palustris* H.), Penncross, for this experiment was collected from putting green of Science Daeduck golf club that managed for 17 years on sand green, that depth of root zone was 15 cm and used sand matched on USGA guideline. pH and electrical conductivity (EC) of root zone sand showed 7.2 and 0.13 dS m^{-1}, respectively (Table 1).

Fertilizers for this experiment was straight fertilizer (SF) and SRF. SF, control fertilizer, was mixed with urea (N 46%), potassium mono phosphate (P_2O_5 52%, K_2O 34%) and potassium chloride (K_2O 60%). SRFs, treatment fertilizers, were SRF-1 (N-P_2O_5-K_2O=15-5-8; IBDU 10%, MU 23%; C&L Chemical Co., Ltd., Seoul, Korea) and SRF-2 (N-P_2O_5-K_2O=15-5-8; MU 33%; C&L Chemical Co., Ltd., Seoul, Korea).

Table 1. Chemical characteristics of soil used in this experiment.

pH (1:5)	EC (dS m^{-1})	OM (%)	T-N (%)	Av.-P_2O_5 (mg kg^{-1})	Ex-K ($cmol_c$ kg^{-1})
7.3	0.16	0.09	0.01	16.0	0.03

EC: Electrical conductivity; OM: Organic matter; T-N: Total nitrogen; Av.-P_2O_5: Available phosphate; Ex-K: Exchangeable potassium.

Treatment establishment

Treatments were designed as follow; non-fertilizer (NF), control fertilizer (CF), SRF-1 (IBDU 10%, MU 23%), and SRF-2 (MU 33%). Experiment of creeping bentgrass applying by SRFs was conducted in pot (1/6,000 a) and every treatment was arranged by a completely randomized block design with three replications. Sand mixed with respective fertilizer (5.0 g N. m^{-2}) was fulfilled in pot on October 1, 2015 and compacted with tap water during 2 days. Then turf of creeping bentgrass collecting from putting green of Science Daeduck golf club with hole cutter (ø10.8 cm, depth 5 cm) was planted at preparing pot on October 5, 2015. SRFs were applied every 3.0 g N. m^{-2} on November 7, 2015, December 14, 2015, January 26, 2016, and February 26, 2016.

Growth investigation and leaf tissue analysis

Growth of creeping bentgrass after fertilizing SRTs was evaluated by visual quality, shoot length, chlorophyll content, clipping yield, top-root (T/R) ratio, nutrient content of turfgrass leaf, and amount of nutrient uptake. Visual quality was investigated with guideline of National Turfgrass Evaluation Program (NTEP) 20 times every weeks (1=worst, 9=best and 6=acceptable). Shoot length was investigated with 30 cm ruler every week during 4 weeks from December 14, January 26, and February 26. Turfgrass growth was investigated with clipping yield on December 14, January 26, February 26, and March 31 by mowing with sterilized clippers. Mowing height of creeping bentgrass was 20 mm from ground. T/R ratio was measured on March 31, 2016, when experiment finish, by gauging dry weight of shoot and root at 70℃ dry oven (JSON-150, JSR, Gongju, Korea). An aliquot in the collected turfgrass leaf in order to measure clipping yield was utilized for measuring chlorophyll content of creeping bentgrass. Chlorophyll content of turfgrass leaf was analyzed by measuring absorbance of solution, that extracted with dimethyl sulfoxide (DMSO) at -20℃ freezer for 24 hour, at UV-spectrophotometer (X-MA 1200, Human, Seoul, Korea) setting 645 nm and 663 nm. Then chlorophyll content such as chlorophyll a, chlorophyll b and total chlorophyll was calculated following numerical formula with absorbance value (Arnon, 1949).

$$\text{Chlorophyll a}=12.7\,A_{663}-2.69A_{645} \quad (1)$$
$$\text{Chlorophyll b}=22.9\,A_{645}-4.68A_{663}$$
$$\text{Total Chlorophyll (a+b)}=20.21\,A_{645}+8.02A_{663}$$

To examine chemical characteristics of sand soil using this study, it was sampled on October 1, 2015, dried at shade, and passed sieve of 2 mm size. There were analyzed pH (1:5), electrical conductivity (EC; 1:5 dilution method), organic matter (O.M; Tyurin method), total nitrogen (T-N; Kjeldahl method), available phosphate (Av-P_2O_5; Bray NO1 method), and exchangeable potassium (Ex-K; 1N-NH_4OAc extraction method) by methods of soil chemical analysis (NIAST, 1998). Content of N, P, and K in leaf tissue was analyzed with dry clippings collected on March 31, 2016. After leaf clipping was digested with sulfuric acid, an analysis of N, P and K was conducted by Kjeldahl method, vanadate-molybdate method with UV-spectrophotometer, and atomic absorption spectrometry with flame photometer (PFP7, JENWAY, Staffordshire, UK). Uptake amount of N, P and K was accounted with clipping yield and its nutrient content as follow formula (Kang et al., 2011; Kim et al., 2001).

$$\text{Uptake amount of N, P and K (g m}^{-2}\text{)}=\text{dry weight of clipping (g m}^{-2}\text{)}\times\text{content of N, P, and K in leaf (\%)} \quad (2)$$

Statistical analysis was utilized Statistical Product and Service Solutions (SPSS) program (SPSS ver. 12.1, IBM, New York, USA). The mean difference of every treatment was evaluated by Duncan multiple range test, and relationship among growth factors by correlation.

Results and Discussion

Growth of creeping bentgrass

As investigated visual quality of creeping bentgrass after SRF fertilized, SRF-1 and SRF-2 was higher than NF or CF (Table 2). SRF-1 and SRF-2 which was different blending ratio of MU and IBDU was not significantly different. As application of SRF, turfgrass color index of Kentucky bluegrass was improved by increasing fertilizer efficiency in root zone (Kim et al., 2009a).

Change of shoot length of creeping bentgrass was measured three times (Table 3). In first investigation (1st SL) from December 14 to January 12, shoot length of SRF-1 and SRF-2 were increased from 21 days treating after treating SRFs (DTA) than that of CF. As compared with CF, Their shoot length were increased from 7 DTA in second investigation (2nd SL) from January 26 to February 24 and from 14 DTA in third investigation (3rd SL) from February 24 to March 31. As compared to CF on 28 DTA, shoot length of SRF-1 and SRF-2 were increased by 39% and 32% in 1st SL, respectively, by 36% in 2nd SL, and by 16% in 3rd SL. These results indicated that application of SRFs was improved by shoot growth creeping bentgrass. Kim et al. (2009a, b) reported that when SRF applied, its N was available in root zone during long time than SF, so that growth and quality of turfgrass improved.

The content of chlorophyll a, chlorophyll b and total chlorophyll of SRF-1 and SRF 2 was analyzed 1,917-2,310, 569-755, 2,487-3,045 $\mu g\ g^{-1}$ and higher than that of NF (982, 241, 1,223 $\mu g\ g^{-1}$) (Table 4). As compared with chlorophyll content of CF, that of SRF treatments was not significantly different except for chlorophyll a content of SRF-1. Kim et al. (2009b) reported that application of IBDU or MU was unaffected a change of chlorophyll of creeping bentgrass.

Clipping yield of SRF-1 and SRF-2 showed 20.4-208.9 dw $g\ m^{-2}$, and was increased by 10.3 folds and 9.7 folds than that of NF, respectively (Table 5). In comparison of CF, SRF-1 and SRF-2 were increased by 85% and 75%, respectively. SRF in root zone was decreased leaching than SF (Guillard and Kopp, 2004) and improved fertilizer efficiency (Kim et al., 2009a) so that it lead better growth and visual quality of turfgrass. It was not significant difference between SRF-1 and SRF-2 excepting investigation on February 26. For, N release rate of SRF in root zone was similar (Kim et al., 2009b).

In investigation of T/R ratio of dry weight of shoot and root after this experiment, dry weight of shoot showed 404-2,368 $g\ m^{-2}$ and of root 1,436-1,899 $g\ m^{-2}$ (Table 6). As compared to CF in dry weight of shoot, SRF-1 and SRF-2 were increased by 50% and 30%, respectively. In investigation of T/R ratio, increase of shoot dry weight after treating SRF was guessed because of increasing clipping yield of turfgrass (Table 5; Kim et al., 2009b)

Table 2. Visual quality of creeping bentrrass after application of slow release fertilizers (SRF).

Treatments[z]	November	December	January	February	March	Average
NF	6.97c	7.01c	7.06c	6.99c	6.89c	6.98c
CF	7.09b	7.19b	7.31b	7.22b	7.21b	7.20b
SRF-1	7.14a	7.25a	7.44a	7.34a	7.35a	7.31a
SRF-2	7.16a	7.26a	7.43a	7.33a	7.35a	7.31a

[z] Treatments were as follows. NF (no fertilizer), CF (control fertilizer; $N-P_2O_5-K_2O$=15-5-8; CF was straight compound fertilizer blending with urea, potassium monophosphate and potassium chloride, 3 g N a.i. m^{-2} $time^{-1}$), SRF-1 [$N-P_2O_5-K_2O$=15-5-8; isobutylidene diurea (IBDU) 10%, methylene urea (MU) 23%, 3 g N a.i. m^{-2} $time^{-1}$], SRF-2 ($N-P_2O_5-K_2O$=15-5-8; MU 33%, 3 g N a.i. m^{-2} $time^{-1}$). Fertilizers were applied 3 g N a.i. m^{-2} on Nov. 5. 2015, Dec. 14. 2015, Jan. 26. 2016, and Feb. 26. 2016.

a-c: Means with the same letters within column are not significantly different by Duncan's multiple range test at $P \leq 0.05$ level.

Table 3. Shoot length of creeping bentrrass after application of slow release fertilizer (SRF).

Treatments[z]	Shoot length (mm)				
	0 DAT	7 DAT	14 DAT	21 DAT	28 DAT
First investigation (Dec. 14-Jan. 12)					
NF	20.0a	29.8b	38.2b	35.2c	32.0c
CF	20.0a	46.2a	50.2a	54.0b	60.0b
SRF-1	20.0a	46.2a	59.8a	63.2a	83.6a
SRF-2	20.0a	46.0a	61.1a	59.3a	79.2a
Second investigation (Jan. 26-Feb. 24)					
NF	20.0a	21.4c	25.0c	25.6c	26.6c
CF	20.0a	29.0b	32.6b	34.8b	31.2b
SRF-1	20.0a	30.9b	39.0a	40.0a	42.3a
SRF-2	20.0a	34.6a	37.7a	42.6a	42.3a
Third investigation (Feb. 24-Mar. 23)					
NF	20.0a	28.4b	27.0c	28.7c	27.3c
CF	20.0a	30.9b	40.6b	46.2b	45.8b
SRF-1	20.0a	40.8a	48.7a	51.2a	53.0a
SRF-2	20.0a	36.9a	46.9a	53.9a	53.1a

[z] Treatments were as follows. NF (no fertilizer), CF (control fertilizer; N-P_2O_5-K_2O=15-5-8; CF was straight compound fertilizer blending with urea, potassium monophosphate and potassium chloride, 3 g N a.i. m^{-2} $time^{-1}$), SRF-1 [N-P_2O_5-K_2O=15-5-8; isobutylidene diurea (IBDU) 10%, methylene urea (MU) 23%, 3 g N a.i. m^{-2} $time^{-1}$], SRF-2 (N-P_2O_5-K_2O=15-5-8; MU 33%, 3 g N a.i. m^{-2} $time^{-1}$). Fertilizers were applied 3 g N a.i. m^{-2} on Nov. 5. 2015, Dec. 14. 2015, Jan. 26. 2016, and Feb. 26. 2016.

a-c: Means with the same letters within column are not significantly different by Duncan's multiple range test at $P \leq 0.05$ level.

Table 4. Chlorophyll content of creeping bentrrass after application of slow release fertilizer (SRF).

Treatements[z]	Chlorophyll (fw g m^{-2})			
	Dec. 14	Jan. 26	Feb. 26	Average
Chlorophyll a				
NF	2,137c	1,708b	1,906b	1,917b
CF	2,704a	1,972a	2,253a	2,310a
SRF-1	2,439b	2,003a	2,210a	2,217a
SRF-2	2,552ab	2,006a	2,126ab	2,228a
Chlorophyll b				
NF	632b	522a	554b	569b
CF	956a	532a	717a	735a
SRF-1	833a	543a	768a	714a
SRF-2	873a	603a	789a	755a
Total chlorophyll				
NF	2,770c	2,230b	2,460b	2,487b
CF	3,660a	2,503ab	2,971a	3,045a
SRF-1	3,272b	2,545ab	2,978a	2,932a
SRF-2	3,424ab	2,609a	2,915a	2,983a

[z] Treatments were as follows. NF (no fertilizer), CF (control fertilizer; N-P_2O_5-K_2O=15-5-8; CF was straight compound fertilizer blending with urea, potassium monophosphate and potassium chloride, 3 g N a.i. m^{-2} $time^{-1}$), SRF-1 [N-P_2O_5-K_2O=15-5-8; isobutylidene diurea (IBDU) 10%, methylene urea (MU) 23%, 3 g N a.i. m^{-2} $time^{-1}$], SRF-2 (N-P_2O_5-K_2O=15-5-8; MU 33%, 3 g N a.i. m^{-2} $time^{-1}$). Fertilizers were applied 3 g N a.i. m^{-2} on Nov. 5. 2015, Dec. 14. 2015, Jan. 26. 2016, and Feb. 26. 2016.

a-c: Means with the same letters within column are not significantly different by Duncan's multiple range test at $P \leq 0.05$ level.

Table 5. Clipping yields of creeping bentgrass after application of slow release fertilizer (SRF).

Treatements[z]	Clipping yield (dw g m^{-2})				
	Dec. 14	Jan. 26	Feb. 26	Mar. 31	Total
NF	2.8c	9.2c	3.2d	5.1c	20.4c
CF	27.0b	47.9b	15.7c	22.5b	113.0b
SRF-1	36.4a	76.4a	37.7a	58.3a	208.9a
SRF-2	37.2a	78.7a	30.0b	52.1a	197.9a

[z] Treatments were as follows. NF (no fertilizer), CF (control fertilizer; N-P_2O_5-K_2O=15-5-8; CF was straight compound fertilizer blending with urea, potassium monophosphate and potassium chloride, 3 g N a.i. m^{-2} $time^{-1}$), SRF-1 [N-P_2O_5-K_2O=15-5-8; isobutylidene diurea (IBDU) 10%, methylene urea (MU) 23%, 3 g N a.i. m^{-2} $time^{-1}$], SRF-2 (N-P_2O_5-K_2O=15-5-8; MU 33%, 3 g N a.i. m^{-2} $time^{-1}$). Fertilizers were applied 3 g N a.i. m^{-2} on Nov. 5. 2015, Dec. 14. 2015, Jan. 26. 2016, and Feb. 26. 2016.

a-c: Means with the same letters within column are not significantly different by Duncan's multiple range test at $P \leq 0.05$ level.

Table 6. T/R ratio of creeping bentgrass after application of slow release fertilizer (SRF).

Treatements[z]	Shoot	Root	T/R ratio
	(g m^{-2})		
NF	404d	1,436b	0.29c
CF	1,583c	1,812a	0.97b
SRF-1	2,368a	1,774a	1.19a
SRF-2	2,063b	1,899a	1.08ab

[z] Treatments were as follows. NF (no fertilizer), CF (control fertilizer; N-P_2O_5-K_2O=15-5-8; CF was straight compound fertilizer blending with urea, potassium monophosphate and potassium chloride, 3 g N a.i. m^{-2} $time^{-1}$), SRF-1 [N-P_2O_5-K_2O=15-5-8; isobutylidene diurea (IBDU) 10%, methylene urea (MU) 23%, 3 g N a.i. m^{-2} $time^{-1}$], SRF-2 (N-P_2O_5-K_2O=15-5-8; MU 33%, 3 g N a.i. m^{-2} $time^{-1}$). Fertilizers were applied 3 g N a.i. m^{-2} on Nov. 5. 2015, Dec. 14. 2015, Jan. 26. 2016, and Feb. 26. 2016.

a-d: Means with the same letters within column are not significantly different by Duncan's multiple range test at $P \leq 0.05$ level.

Uptake of nutrient in leaf tissue of creeping bentgrass

After treated SRF, the content of N, P and K in the turfgrass leaf was 1.52-2.10, 0.14-0.25, and 0.53-1.96%, respectively (Table 7). As compared with NF, N content of SRF-1 and SRF-2 was not significantly different and P and K increased. In comparison with CF, N content of SRF-1 and SRF-2 was decreased 27.6% and 13.3%, respectively and P and K were not significantly different. Kim et al. (2009b) reported that N content of SF in leaves of creeping bentgrass was higher than that of SRF.

Table 7. Content of and taken amount of nutrient in creeping bentgrass after application of slow release fertilizer (SRF).

Treatments[y]	Nutrient content of leaf (%)			Taken up amount of nutrient (g m^{-2})[z]		
	N	P	K	N	P	K
NF	1.63bc	0.14b	0.53c	0.34d	0.03c	0.11c
CF	2.10a	0.24a	1.54b	2.37c	0.28b	1.73b
SRF-1	1.52c	0.24a	1.96a	3.17b	0.50a	4.10a
SRF-2	1.82b	0.25a	1.88a	3.60a	0.49a	3.73a

[y] Treatments were as follows. NF (no fertilizer), CF (control fertilizer; N-P_2O_5-K_2O=15-5-8; CF was straight compound fertilizer blending with urea, potassium monophosphate and potassium chloride, 3 g N a.i. m^{-2} $time^{-1}$), SRF-1 [N-P_2O_5-K_2O=15-5-8; isobutylidene diurea (IBDU) 10%, methylene urea (MU) 23%, 3 g N a.i. m^{-2} $time^{-1}$], SRF-2 (N-P_2O_5-K_2O=5-5-8; MU 33%, 3 g N a.i. m^{-2} $time^{-1}$). Fertilizers were applied 3 g N a.i. m^{-2} on Nov. 5. 2015, Dec. 14. 2015, Jan. 26. 2016, and Feb. 26. 2016.

[z] Taken up amount of nutrient=total dry weight×nutrient content of leaf.

a-d: Means with the same letters within column are not significantly different by Duncan's multiple range test at $P \leq 0.05$ level.

Taken up amount of N, P and K in creeping bentgrass by treating SRF was 0.34-3.60, 0.03-0.49, 0.11-3.73 g m^{-2} and those in SRF treatments increased than those of NF or CF (Table 7). When compared with CF, uptake amount of SRF-1 and SRF-2 was increased by 34% and 52%, P by 86% and 79% and K by 136% and 115%. SRF was lower leaching than CF in the sand green so that growth and quality of turfgrass was improved by increasing fertilizer efficiency (Guillard and Kopp, 2004; Kim et al., 2009b)

Uptake rate of N of CF, SRF-1 and SRF-2 was 15, 20, and 23%, respectively, P 12, 23, and 23%, and K 26, 65, and 59% (data no showed). Nutrient uptake rate of SRF-1 and SRF-2 was raised than that of CF, because SRF application in creeping bentgrass promoted shoot growth (Table 5 and Table 6) and nutrient uptake (Table 7). Guillard and Kopp (2004) reported that applying natural SRF like organic fertilizers could be declined water pollution of lakes because of low leaching and run-off, and Kim et al. (2009b) that fertilizing SRF on putting green improved remaining time of available N content in root zone. Creeping bentgrass in root zone enhancing available N such as ammonium-N and nitrate-N made progress a turfgrass growth and visual quality so that N uptake in turfgrass management of golf course was the important key of turfgrasss growth (Kussow et al., 2012). These results and reviews showed that SRF application in turfgrass management was improved turfgrass growth and quality by prompting N uptake because of sustaining available N content in the root zone.

Conclusion

Slow release N fertilizer (SRF) is fertilizer releasing N to turfgrass slowly over some time after irrigation. Superintendents had applied SRF for turfgrass management on golf course a long time. In this experiment, influences of SRF on growth and quality of creeping bentgrass were evaluated with visual quality, shoot length, chlorophyll content, clipping yield, T/R ratio, nutrient content in leaf tissue, and N efficiency after fertilizing SRF. Treatments were designed as follow; non-fertilizer (NF), control fertilizer (CF), SRF-1 (IBDU 10%, MU 23%), and SRF-2 (MU 33%). As applied SRF, visual quality, shoot length, clipping yield, T/R ratio and N uptake of creeping bentgrass was increased than that of CF. Amount of N uptake was positively correlated to visual quality, shoot length, total chlorophyll content, clipping yield, and dry weight of shoot and root ($P<0.01$). N efficiency of SRF-1 and SRF-2 increased by 39% and 61% than that of CF, respectively. These results demonstrated that application of slow release nitrogen fertilizer improved turfgrass quality and shoot growth of creeping bentgrass by prompting N uptake.

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Reference

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts polyphenoloxidase in beta vulgaris. Plant Physiol. 24(1):1-15.

Cheong, J.I. 1996. Effects of slow release fertilizer application on rice grain at different culture methods. Kor. J. Crop Sci. 41(3):286-294. (In Korean)

Guillard, K. and Kopp, K.K. 2004. Nitrogen fertilizer from and associated nitrate leaching from cool-season lawn turf. J. Environ. Qual. 33:1822-1827.

Kang, S.S., Kim, M.K., Kwon, S.I., Kim, M.S., Yoon, S.W., et al. 2011. The effect of application levels of slurry and bio-filtration liquid fertilizer on soil chemical properties and growth of radish and corn. Kor. J. Soil Sci. Fert. 44(6):1306-1313. (In Korean)

Kim, J.W., Kim, C.H., Baeck, J.H., Lee, D.J., Choi, Y.S., et al. 2001. An introduction to soil and fertilizer. pp. 240-258. Sunjin Press, Goyang, Korea. (In Korean)

Kim, Y.S., Ham, S.K. and Lim, H.J. 2010. Change of soil physicochemical properties by mixed ratio of 4 types of soil amendments used in golf course. Kor. Turfgrass Sci. 24(2):205-210. (In Korean)

Kim, Y.S., Kim, T.S., Ham, S.K., Bang, S.W. and Lee, C.E. 2009a. The effect of compound fertilizer contained slow release nitrogen on turfgrass growth in Kentucky bluegrass and on nitrogen change in root zone. Kor. Turfgrass Sci. 23(1):101-110. (In Korean)

Kim, Y.S., Kim, T.S., Ham, S.K., Bang, S.W. and Lee, C.E. 2009b. The effect of compound fertilizer contained slow release nitrogen on turfgrass growth in creeping bentgrass and on change in soil nitrogen. Kor. Turfgrass Sci. 23(1):111-122. (In Korean)

Kussow, W.R., Soldat, D.J., Kreuser, W.C. and Houlihan, S.M. 2012. Evidence, regulation, and consequences of nitrogen-driven nutrient demand by Turfgrass. ISRN Agronomy 10:1-9.

Lee, E.T., Cho, S.K., Song, Y.S., Jang, Y.S., Choi, I.H., et al. 2001. Effects of a slow-release fertilizer on onion (*Allium cepa* L.) cultivation in south western area. Kor. J. Hort. Sci. & Technol. 19(4):476-482. (In Korean)

Lee, K.Y., Park, C.W., Park, K.L., Kim, J.G., Lee, D.B., et al. 2005. Nitrogen balance in paddy soil of control-release fertilizer application. Kor. J. Soil Sci. Fert. 38(3):157-163. (In Korean)

NIAST (National Institute of Agricultural Science and Technology). 1998. Methods of soil chemical analysis. NIAST, RDA, Suwon, Korea. (In Korean)

Park, K.W. and Choy, J.H. 1986. Study on the development and application of slow releasing fertilizer using Korean nature clay minerals. Kor. J. Environ. Agric. 5(2):135-140. (In Korean)