

Research Article



CrossMark

Open Access

Saccharomyces cerevisiae HS-1와 *Streptococcus thermophiles* HS-2 함유 복합 미생물비료 처리 후 크리핑 벤투그래스의 생육

김영선¹, 이금주^{2*}

¹

²

Growth of Creeping Bentgrass after Application of Microbial Fertilizer Containing *Saccharomyces cerevisiae* HS-1 and *Streptococcus thermophiles* HS-2

Young-Sun Kim¹ and Geung-Joo Lee^{2*} (¹Department of Horticultural Science, College of Natural and Life Sciences, Daegu University, Gyeongsan 38453, Korea, ²Department of Horticultural Science, College of Agriculture Life Sciences, Chungnam National University, Daejeon 34134, Korea)

Received: 03 November 2023/ Revised: 28 November 2023/ Accepted: 30 November 2023

Copyright © 2023 The Korean Society of Environmental Agriculture

This is an Open-Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ORCID

Young-Sun Kim

<https://orcid.org/0000-0002-5645-7021>

Geung-Joo Lee

<https://orcid.org/0000-0002-3774-1860>

Abstract

This study was conducted to evaluate the effects of soil microbial fertilizer (SMF) containing *Saccharomyces cerevisiae* HS-1 and *Streptococcus thermophiles* HS-2 on the growth of creeping bentgrass. For the pot experiment, the treatments were as follows: no fertilizer (NF), control (3 N g/m²/month), SMF-1 (control+SMF 2 mL/m²/time), and SMF-2 (control+SMF 4 mL/m²/time). For the plot experiment, the treatments were as follows: NF, control, SMFp-1 (control+SMF 1 mL/m²/time), SMFp-2 (control+SMF 2 mL/m²/time), and SMFp-3 (control+SMF 4 mL/m²/time). In the pot experiment, visual turfgrass quality and the uptake amount of nitrogen (N) and potassium (K) were increased under the SMF treatments, whereas the content of chlorophyll (a, b, and a+b) and clipping yield were not considerably different compared with the control. In the pot experiment, the amount of SMF positively correlated with visual turfgrass quality and uptake amount of N and K. In the plot experiment, turfgrass density was increased by 12.9-19.2% under

SMFp treatments compared with the control. These results indicated that the application of SMF containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 improved the quality, density, and growth of creeping bentgrass via prompting the uptake of N and K.

Key words: Creeping bentgrass, K uptake, N uptake, Soil microbial fertilizer, Turfgrass growth

서 언

[1].

[2-5].

(plant growth prompting rhizobacteria, PGPR)

[6].

[7].

* Corresponding author: Geung-Joo Lee

Phone: +82-42-821-5734; Fax: +82-42-821-8888;

E-mail: gjee@cnu.ac.kr

	(<i>Sa. cerevisiae</i> HS-1)	(<i>St. thermophiles</i> HS-2)
[8].		
[9].		
[10].		
[11]		
[12]		
[13].		
[14].		
[15].		
[16].		
[17].		
[18].		
[19].		
et al.[20]		

재료 및 방법

공시재료

2012 8 2013 10 1 2
A

B (N-P₂O₅-K₂O=21-17-17; Namhae Chemical Corp., Yeosu, Korea)
(*Sa. cerevisiae* HS-1, 3.6 × 10⁷ cfu mL⁻¹,
St. thermophiles HS-2, 3.9 × 10⁷ cfu mL⁻¹; Hyosung O&B, Asan, Korea)

(*A. stolonifera* L.)

'Penn A-1'

'Penncross' (United States Golf Association, USGA)

() (Table 1),

(country club, CC)

CC 1992

22

Table 1, 2

복합미생물제제 포트시험

2012 8 2013 2 6
UGSA 3 inch

Table 1. Particle size distribution of sand soil used in the experiment

Experiment	Particle size (mm)						
	4.00 over	4.00-2.00	2.00-1.00	1.00-0.50	0.50-0.25	0.25-0.15	0.15-0.053
Pot	-	1.1	5.7	41.3	44.8	5.9	1.2
Plot	-	0.2	5.2	36.6	48.1	7.9	2.1
USGA standard	0%	10% below		60% over		20% below	10% below

USGA: United States Golf Association.

Table 2. The chemical properties of soil used in this experiment

Experiment	pH	EC	OM	T-N	Av-P ₂ O ₅	Ex-K	CEC
	(1:5)	(dS/m)	(%)		(mg/kg)	(cmol _c /kg)	
Pot	7.21	0.99	0.46	0.03	18	0.05	2.05
Plot	7.03	0.24	0.99	0.03	20	0.04	2.51

EC: electrical conductivity; OM: organic matter; T-N: total nitrogen; Ex-K: exchangeable potassium; CEC: cation exchangeable capacity.

2012 8 가 (shoot) (root)

6 10 g m⁻² 가 2

11 5 20 mm 2 mm

가 10-26°C 60-75%

(soil microbial fertilizer, SMF) (non-fertilizer),

(control, compound fertilizer 3 N g/m²/month),

1 (SMF-1, SMF 2 mL/m²/time)

2 (SMF-2, SMF 4 mL/m²/time)

SMF

SMF-1 SMF-2

3 inch (75 mm)

3 14.3 g/m²/month (3 N g/m²/month)

1,000 mL (KS-10-2, Kwang Sung Co., Ltd., Daejeon, Korea) 11 5 , 12

3 , 1 7 , 2 4 4

SMF

1,000 mL 14.3 g/m² 1,000 mL

11 5 7 16 (KS-10-2, Kwang Sung Co. Ltd., Daejeon, Korea) 2013 5 1 , 5 30 , 7 6 , 8

1-2 2 , 9 5 5 SMF

가 1,000 mL 5 1, 15, 30 , 6 14 , 7 6, 24 , 8 2, 18 , 9 5, 26 10

7 17 가 가 National Turf-grass Evaluation Program (NTEP) (GM262B-AC9, Sibaura, Tokyo, Japan) 2-4 4 mm

(scale: 1-9, 1: worst, 6: acceptable and 9: best).

12 3 , 1 7 2 4 3 가 (2 , 6 13 , 8 18) (1 , 9 5) , (2 , 8 16 , 9 5)

20 mm 70% 가 70°C (JSON-150, JSR, Gongju, Korea) 24 가 , 가 ,

0.1 g 가 , 가 ,

() 95% (Samchun, Seoul, Korea) 5 1 10 ,

10 mL 가 -4°C 가 . 가

48 UV- 648 NTEP

nm (A₆₄₈) 664 nm (A₆₆₄) Turf color meter (TCM 500, Spectrum Technologies, Inc., Plainfield, IL, USA) Chlorophyll meter (CM 1000, Spectrum Technologies, Inc., Plainfield, IL, USA)

[21].

Chlorophyll a = 13.36A₆₆₄ - 5.19A₆₄₈

Chlorophyll b = 27.45A₆₄₈ - 8.12A₆₆₄

Chlorophyll a+b = 5.24A₆₄₈ + 22.24A₆₆₄

2 28 . (1.0 cm², 1 cm × 1 cm) 6 14 ,

7 24 , 8 18 , 9 26 4 , 통계분석
 4.0 mm 5 SMF SPSS (ver 25.0,
 31 , 7 6 , 8 2 , 9 4 , 10 10 5 IBM, New York, USA) ANOVA
 . Duncan
 , T- SMF
 , SMF Pearson
 70°C 24

토양 화학성 및 식물체 분석

결과 및 고찰

(:
 2012 8 1 , : 2013 5 1) (:
 : 2013 2 28 , : 2013 10 10)
 , 2 mm
 pH, (EC, elec-
 trical conductivity), (OM, organic matter),
 (T-N, total nitrogen), (Av-P₂O₅, available phos-
 phate), (Ex-K, exchangeable potassium
 (CEC, cation exchangeable capacity)
 . pH EC 1:5
 , OM Tyurin , T-N Kjeldahl , Av-
 P₂O₅ Bray No.1 , CEC 1N-NH₄OAc
 (2013 2 28)
 가 (pH
) 0.2 g 25 mL 1 mL 가
 Kjeldahl pH가
 Kjeldahl ,
 UV-spectrophotometer (X-MA1200, Human, Seoul,
 Korea)
 (PFP7, Jenway, Staffordshire, UK)
 SMF
 (Table 4). NF
 , 11 ,
 12 1 , 2
 가 , SMF
 (SMF-1, SMF-2) NF SMF

복합미생물제제 포트시험
 SMF
 (Table 3).
 EC Av-P₂O₅ , OM T-N
 가 (Table 2, 3). EC Av-P₂O₅가
 , OM T-N 가
 [22].
 (NF) , SMF pH
 , EC, OM, T-N, Av-P₂O₅, Ex-K CEC
 SMF-2 pH가 , SMF-1
 pH가 [23]. Lee et al.[24]
 SMF 가
 (Table 4). NF SMF
 , 11 ,
 12 1 , 2
 가 , SMF
 (SMF-1, SMF-2) NF SMF

Table 3. The chemical properties of soil after SMF application in the pot experiment

Treatment ¹⁾	pH (1:5)	EC (dS/m)	OM (%)	T-N	Av-P ₂ O ₅ (mg/kg)	Ex-K (cmol _c /kg)	CEC
NF	7.23a ²⁾	0.28a	0.46a	0.03a	18a	0.05a	2.05a
Control	6.93b	0.31a	0.43a	0.02a	31a	0.07a	2.21a
SMF-1	6.80c	0.31a	0.40a	0.02a	24a	0.06a	1.93a
SMF-2	6.46d	0.25a	0.47a	0.02a	28a	0.06a	2.13a

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMF-1 (Control+SMF 1 mL/m²) and SMF-2 (Control+SMF 2 mL/m²). Compound fertilizer was fertilized in the treatments on November 5, December 3, January 7, and February 4. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 16 times every week from November 5, 2012 to February 18, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level. EC: electrical conductivity, T-N: total nitrogen, Av-P₂O₅: available phosphate, Ex-K: exchangeable potassium, CEC: cation exchangeable capacity.

Table 4. The changes of visual quality in the creeping bentgrass after applying SMF in the pot experiment

Treatment ¹⁾	Visual quality (scale: 1-9, 1: worst, 6: acceptable, 9: best)				
	November	December	January	February	Average
NF	6.47d ²⁾	6.66c	6.43c	6.29b	6.46c
Control	6.92c	7.14b	7.21b	7.3a	7.14b
SMF-1	7.09b	7.22a	7.29a	7.39a	7.25a
SMF-2	7.15a	7.22a	7.35a	7.30a	7.25a
Correlation ³⁾	**	*	**	NS	**

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMF-1 (Control+SMF 1 mL/m²) and SMF-2 (Control+SMF 2 mL/m²). Compound fertilizer was fertilized in the treatments on November 5, December 3, January 7, and February 4. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 16 times every week from November 5, 2012 to February 18, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.

³⁾NS, * and ** were not significant and a significant at the 0.05 and 0.01 probability level by correlation coefficient between control and amount applying SMF (N=9).

SMF 가 가 가 가 가
 12 1 2 11 , [15]. *St. thermohylyus* HS-2
 (R=0.840**, p=0.005) [25].
 SMF 가 가 가 가 가 [26].
 SMF (Table 6). SMF
 a, b a+b 322-1,266 µg/g, 가 , 11 29
 151-519 µg/g, 473-1,695 µg/g (Table 2 28 , 12 29 1
 5). NF SMF , 28 SMF 28 SMF
 2 28 SFM-1 38.9% 가
 , 11 29 , 12 29 1 28 가
 11 29 SMF-1 SMF-2 SMF [26].
 75.3% 94.7% 가 12 29 , 1 28 NF
 2 28 SMF SMF SMF
 SMF-2 60.1% 28.3% 가 SMF
 , 11 29 , 12 29 1 28 SMF
 , SMF SMF (Table 7).
 , SMF a+b 480-1,238 g/m² ,
 (R=0.687*, p=0.041) 706-1,137 g/m² . SMF
 SMF 가 가 2.56-2.58 1.51-1.61
 가 가 NF , T/R
 가 [2, T/R SMF 가
 3] [15]. SMF SMF SMF
Sa. cerevisiae HS-1 1,233 µg/ . SMF
 mL , T/R

Table 5. The changes of chlorophyll content in the creeping bentgrass after applying SMF in the pot experiment

Treatment ¹⁾	Chlorophyll content (µg/g)				
	Nov 29	Dec 29	Jan 28	Feb 28	Average
Chlorophyll a					
NF	559 b ²⁾	637 b	322 b	461 c	495 b
Control	785 ab	1,270 a	857 a	1,035 b	987 a
SMF-1	976 ab	938 ab	1,138 a	1,707 a	1,190 a
SMF-2	1,090 a	1,266 a	1,039 a	1,427 ab	1,205 a
Correlation ³⁾	NS	NS	NS	NS	NS
Chlorophyll b					
NF	178 b	164 a	151 b	202 c	174 b
Control	171 b	272 a	391 a	285 ab	280 a
SMF-1	312 a	217 a	519 a	408 a	364 a
SMF-2	333 a	325 a	468 a	267 b	348 a
Correlation	*	NS	NS	NS	NS
Chlorophyll a+b					
NF	737 b	801 b	473 b	664 c	669 b
Control	956 ab	1,543 a	1,248 a	1,321 b	1,267 a
SMF-1	1,288 ab	1,155 ab	1,656 a	2,115 a	1,554 a
SMF-2	1,423 a	1,591 a	1,507 a	1,695 ab	1,554 a
Correlation	NS	NS	NS	NS	*

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMF-1 (Control+SMF 1 mL/m²) and SMF-2 (Control+SMF 2 mL/m²). Compound fertilizer was fertilized in the treatments on November 5, December 3, January 7, and February 4. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 16 times every week from November 5, 2012 to February 18, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.

³⁾NS and * were not significant and a significant at the 0.05 probability level by correlation coefficient between control and amount applying SMF (N=9).

Table 6. The changes of clipping yield in the creeping bentgrass after applying SMF in the pot experiment

Treatment ¹⁾	Clipping yield (dry weight g/m ²)				
	Nov 29	Dec 29	Jan 28	Feb 28	Total
NF	20.3 c ²⁾	26.0 b	13.8 b	22.2 c	82.4 b
Control	61.0 b	104.0 a	125.4 a	94.9 b	385.2 a
SMF-1	94.3 a	98.0 a	135.7 a	127.8 a	455.8 a
SMF-2	95.1 a	97.3 a	140.5 a	106.2 b	439.1 a
Correlation ³⁾	NS	NS	NS	NS	NS

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMF-1 (Control+SMF 1 mL/m²) and SMF-2 (Control+SMF 2 mL/m²). Compound fertilizer was fertilized in the treatments on November 5, December 3, January 7, and February 4. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 16 times every week from November 5, 2012 to February 18, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.

³⁾NS was not significant by correlation coefficient between control and amount applying SMF (N=9).

SMF (Table 8). SMF-2 33.6% 가 SMF 1.38-3.30% , SMF 1.35-2.52%, 0.11-0.26%, (R=0.742*, p=0.022)

Table 7. The dry weight of shoot and root in the creeping bentgrass after applying SMF in the pot experiment

Treatment ¹⁾	Shoot (g/m ²)		Root	T/R ratio
NF	480 b ²⁾		706 b	0.68 b
Control	1,049 a		1,137 a	0.93 a
SMF-1	1,229 a		1,134 a	1.11 a
SMF-2	1,238 a		1,065 a	1.17 a
Correlation ³⁾	NS		NS	NS

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMF-1 (Control+SMF 1 mL/m²) and SMF-2 (Control+SMF 2 mL/m²). Compound fertilizer was fertilized in the treatments on November 5, December 3, January 7, and February 4. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 16 times every week from November 5, 2012 to February 18, 2013.
²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.
³⁾NS was not significant by correlation coefficient between control and amount applying SMF (N=9).

Table 8. The nutrient content and uptake amount of turfgrass leaf in the creeping bentgrass after applying SMF in the pot experiment

Treatment ¹⁾	Nutrient content (%)			Uptake amount (g/m ²)		
	N	P	K	N	P	K
NF	1.35 b ²⁾	0.11 b	1.38 c	1.11 c	0.10 b	1.14 c
Control	2.05 ab	0.19 ab	2.47 b	7.83 b	0.80 ab	9.44 b
SMF-1	2.10 ab	0.30 a	2.72 ab	9.60 ab	1.39 a	12.38 a
SMF-2	2.52 a	0.26 ab	3.30 a	10.93 a	1.17 a	14.44 a
Correlation ³⁾	NS	NS	*	*	NS	**

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMF-1 (Control+SMF 2 mL/m²) and SMF-2 (Control+SMF 4 mL/m²). Compound fertilizer was fertilized in the treatments on November 5, December 3, January 7, and February 4. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 16 times every week from November 5, 2012 to February 18, 2013.
²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.
³⁾NS, * and ** were not significant and a significant at the 0.05 and 0.01 probability level by correlation coefficient between control and amount applying SMF (N=9).

가
 1.11-10.93 g/m², 0.10-1.17 g/m², 1.14-14.44 g/ m²
 SMF
 SMF-2 SMF-1 SMF-2 SMF 가 2 가 [29].
 SMF-2 SMF-2 가 8.82 가 (Table 10). 7.74-
 ()
 SMF 145-420
 [27]. SMF 가 [27]. SMF 가 SMF
 복합미생물제제 포장시험
 SMF SMFp-2 T-
 (Table 9). NF SMFp SMF
 SMF 가

Table 9. The chemical properties of soil after SMF application in the plot experiment

Treatment ¹⁾	pH	EC	OM	T-N	Av-P ₂ O ₅	Ex-K	CEC
	(1:5)	(dS/m)	(%)		(mg/kg)	(cmol _c /kg)	
NF	7.03 a ²⁾	0.23 a	0.98 a	0.03 a	17 a	0.04 a	2.57 a
Control	6.99 a	0.26 a	0.96 a	0.04 a	25 a	0.04 a	2.54 a
SMFp-1	6.99 a	0.22 a	1.03 a	0.04 a	17 a	0.04 a	2.51 a
SMFp-2	7.06 a	0.24 a	1.09 a	0.04 a	22 a	0.04 a	2.47 a
SMFp-3	7.07 a	0.23 a	1.00 a	0.04 a	17 a	0.05 a	2.57 a

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMFp-1 (Control+SMF 1 mL/m²), SMFp-2 (Control+SMF 2 mL/m²) and SMFp-3 (Control+SMF 4 mL/m²). Compound fertilizer was fertilized in the treatments on May 1, May 31, July 6, August 2, and September 5. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 10 times on May 1, May 15, May 31, June 14, July 6, July 24, August 2, August 18, September 5, and September 26, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.

Table 10. The changes of clipping yield in the creeping bentgrass after applying SMF in the plot experiment

Treatment ¹⁾	Investigation date (Month/day)									Average
	5/15	5/31	6/14	7/6	7/24	8/2	9/5	9/26	10/10	
Turf color index										
NF	8.12 a ²⁾	8.08 a	8.18 b	8.63 a	8.49 a	8.74 a	8.74 a	7.86 a	7.78 a	7.74 a
Control	8.16 a	8.52 a	8.81 a	8.82 a	8.51 a	8.48 b	8.61 a	8.30 a	7.84 a	7.89 a
SMFp-1	8.16 a	8.41 a	8.76 a	9.14 a	8.54 a	8.44 b	8.64 a	8.31 a	7.96 a	7.93 a
SMFp-2	8.17 a	8.52 a	8.82 a	8.87 a	8.57 a	8.52 b	8.74 a	8.36 a	7.94 a	7.94 a
SMFp-3	8.15 a	8.35 a	8.75 a	8.84 a	8.49 a	8.54 ab	8.75 a	8.28 a	7.94 a	7.90 a
Correlation ³⁾	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T-test ⁴⁾	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorophyll index										
NF	208 b	145 b	191 b	189 b	230 a	222 a	240 a	223 a	233 a	209 b
Control	288 ab	203 a	416 a	304 a	232 a	215 a	225 a	233 a	244 a	262 a
SMFp-1	300 a	212 a	414 a	283 a	225 a	216 a	236 a	225 a	244 a	262 a
SMFp-2	295 ab	212 a	420 a	282 a	234 a	214 a	242 a	243 a	252 a	266 a
SMFp-3	273 ab	222 a	395 a	290 a	221 a	208 a	235 a	232 a	246 a	258 a
Correlation ³⁾	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T-test ⁴⁾	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMFp-1 (Control+SMF 1 mL/m²), SMFp-2 (Control+SMF 2 mL/m²) and SMFp-3 (Control+SMF 4 mL/m²). Compound fertilizer was fertilized in the treatments on May 1, May 31, July 6, August 2, and September 5. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 10 times on May 1, May 15, May 31, June 14, July 6, July 24, August 2, August 18, September 5, and September 26, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.

³⁾NS was not significant by correlation coefficient between control and amount applying SMF (N=12).

⁴⁾NS was not significant by t-test between control and SMFp-2 treatment.

a+b SMF (Table 4, 5) . (data
1 no shown)[29] 가
2-4 (Table 11).
가 [28]. . NF
SMF , SMF 가 가

Table 11. The changes of clipping yield in the creeping bentgrass after applying SMF in the plot experiment

Treatment ¹⁾	Turfgrass density (No. of tiller/cm ²)				
	Jul 14	Jul 24	Aug 18	Sep 26	Average
NF	17.3 b ²⁾	20.3 c	20.7 d	21.5 b	20.0 c
Control	20.3 ab	27.7 b	24.7 c	23.0 b	24.0 b
SMFp-1	26.3 a	27.0 b	28.0 b	27.1 a	27.1 a
SMFp-2	25.7 a	25.3 b	32.7 a	28.7 a	28.1 a
SMFp-3	25.0 a	32.3 a	30.3 ab	26.9 a	28.6 a
Correlation ³⁾	NS	*	*	NS	**
T-test ⁴⁾	NS	NS	**	**	**

¹⁾Treatments were as follow. NF: non-fertilizer, control: compound fertilizer (N-P₂O₅-K₂O=21-17-17; 14.3 g/m²), SMFp-1 (Control+SMF 1 mL/m²), SMFp-2 (Control+SMF 2 mL/m²) and SMFp-3 (Control+SMF 4 mL/m²). Compound fertilizer was fertilized in the treatments on May 1, May 31, July 6, August 2, and September 5. Soil microbial fertilizer (SMF) containing *Sa. cerevisiae* HS-1 and *St. thermophiles* HS-2 was applied 10 times on May 1, May 15, May 31, June 14, July 6, July 24, August 2, August 18, September 5, and September 26, 2013.

²⁾Means with the same letters within column are not significantly different by Duncan's multiple range test at p≤0.05 level.

³⁾NS, * and ** were not significant and a significant at the 0.05 and 0.01 probability level by correlation coefficient between control and amount applying SMF (N=12).

⁴⁾NS and ** were not significant and a significant at the 0.01 probability level by t-test between control and SMFp-2 treatment.

SMF 가 , SMF 가 , SMFp-1, SMFp-2 , SMFp-3 12.9%, 17.1%, 19.2% , SMF 가 가 SMFp-2 T- , 8 18 가 12.9-19.2% (Sa. cerevisiae HS-1) (St. thermophiles HS-2) SMF 가 가 . SMF 7 24 8 18 가 (R_{7/24}=0.579*, p=0.048; R_{8/18}=0.637*, p=0.026)

(R_{7/24}=0.729*, p=0.007)

Note

The authors declare no conflict of interest.

References

1. Jeong J (2006) Guideline for basic standard for organic rice cultivation. Korean Journal of Organic Agriculture, 10(4), 1-7.
2. Shin S, Yundendorj K, Lee SS, Lee DH, Kang KH, Kahng HY (2013) Characterization and organic hydrocarbons degradation potential of euryhaline marine microorganism, *Bacillus* sp. EBW 4 isolated from polychaete (*Perinereis aibuhitensis*). Korean Journal of Microbiology, 49(1), 38-45. <https://doi.org/10.7845/kjm.2013.005>.
3. Park K, Park GT, Kim SM, Lee CY, Son HJ (2008) Conditions for soluble phosphate production by environ-

결론 및 고찰

(*Sa. cerevisiae* HS-1) (*St. thermophiles* HS-2) (soil microbial fertilizer, SMF) (NF), (control, 3 N g/m²/month), SMF-1 (control + SMF 2 mL/m²/time) SMF-2 (control + SMF 4 mL/m²/time) , (NF), (control, 3 N g/m²/month), SMFp-1 (control + SMF 1 mL/m²/time), SMFp-2 (control + SMF 2 mL/m²/time) SMFp-3 (control + SMF 4 mL/m²/time) , SMF 가

[28].

- ment-friendly biofertilizer resources, *Pseudomonas fluorescens*. *Journal of the Environmental Sciences*, 17(9), 1033-1037.
<https://doi.org/10.5322/JES.2008.17.9.1033>.
4. Jung WC, Shin TS, Do KS, Kim WK, Lee JH, Choi KH (2006) Development of antagonistic microorganism for biological control of *Phytium blight* of turfgrass. *Research in Plant Disease*, 12(3), 260-266.
<https://doi.org/10.5423/RPD.2006.12.3.260>.
 5. Sea S, Kim Y (2011) Development of "Bt-Plus" biopesticide using entomopathogenic bacterial (*Xenorhabdus nematophila*, *Photorhabdus temperate* spp. Temperate). *Korean Journal of Applied Entomology*, 50(3), 171-178.
<https://doi.org/10.5656/KSAE.2011.07.0.24>.
 6. Huynh Le TT, Jun SE, Kim GT (2019) Current perspectives on the effects of plant growth-promotion rhizobacteria. *Journal of Life Science*, 29(11), 1281-1293. <https://doi.org/10.5352/JLS.2019.29.11.1281>.
 7. Cho SR, Kim JH, Shim SR (2015) Practical use of several ground covers on a slope revegetation construction. *Journal of the Korean Society of Environmental Restoration Technology*, 18(3), 97-107.
<https://doi.org/10.13087/kosert.2015.18.3.97>.
 8. Yoo MJ, Lee JP, Joo YK, Kim DH (2009) Analysis of maintenance expense in various golf course. *Korean Journal of Turfgrass Science*, 23(1), 61-76.
 9. Kim SK (2003) A master plan for the 2002 world cup sports complex in the Suwon city, Korea. *Journal of Korean Institute of Landscape Architecture*, 30(6), 119-127.
 10. Kato M (2005) Integral turf management for reducing pesticide usage in Japanese golf course. *Korean Journal of Turfgrass Science*, 19(2), 161-175.
 11. Ham SK, Lim JY, Lee YM (2014) Livestock liquid fertilizer utilization study of zoysiagrass growing in the field. *Journal of the Korea Organic Resource Recycling Association*, 22(4), 11-20.
<https://doi.org/10.17137/Korrae.2014.22.4.011>.
 12. Ryu JH, Shim GY, Kim KS (2014) Inhibition of *in vitro* growth of tree soil-borne turfgrass diseases by antagonistic bacteria from composted liquid manure. *Korean Journal of Horticultural Science and Technology*, 32(6), 879-886.
<https://doi.org/10.7235/hort.2014.14085>.
 13. Kim JG, Ahn JH (2011) Comparative study on ethanol production with pentose and/or hexose by *Saccharomyces cerevisiae* and/or *Pichia stipites*. *Journal of Life Science*, 21(3), 335-340.
<https://doi.org/10.5352/JLS.2011.21.3.335>.
 14. Prusty R, Grisafi P, Fink GR (2004) The plant hormone indoleacetic acid induces invasive growth in *Saccharomyces cerevisiae*. *Biological Science*, 101(12), 4153-4157. <https://doi.org/10.1073/pnas.0400659101>.
 15. Kim DS, Shin HY, Han SI (2022) Isolation of indole-3-acetic acid (IAA) producing *Arthrobacter* sp. and plant growth promotion effect. *Journal of the Korean Applied Science and Technology*, 39(6), 831-838.
<https://doi.org/10.12925/jkocs.2022.39.6.831>.
 16. Kim DC, In MJ (2016) Preparation and characteristics of yogurt added with Korean rice wine lees powder. *Journal of Applied Biological Chemistry*, 59(4), 345-349. <https://doi.org/10.3839/jabc.2016.058>.
 17. Kim BK, Hong KJ, Park JH, Kim HS, Kim YJ (2005) Effects of dietary microbes additive on growth performance and meat quality in pigs and broiler chick. *Korean Journal for Food Science of Animal Resources*, 25(2), 134-140.
 18. Abdhul K, Ganesh M, Shanmughapriya S, Kanagavel M, Anbarasu K, Natarajaseenivasan K (2014) Antioxidant activity of exopolysaccharide form probiotic strain *Enterococcus faecium* (BDU7) form Ngari. *International Journal of Biological Macromolecules*, 70, 450-454.
<https://doi.org/10.1016/j.ijbiomac.2014.07.026>.
 19. Bae EJ, Lee KS, Park NS, Huh MR (2012) Comparison of oxidative damage in zoysiagrass (*Zoysia* spp.) with environmental stress. *Journal of Korean Society for People, Plant and Environment*, 15(2), 107-113.
 20. Kim YS, Ham SK, Lee SJ (2010) Effect of liquid fertilizer contained medium of *Lactobacillus* sp. and *Saccharomyces* sp. on growth of creeping bentgrass. *Korean Journal of Turfgrass Science*, 24(2), 138-144.
 21. Miazek K, Ledakowicz S (2013) Chlorophyll extraction from leaves, needles and microalgae: A kinetic approach. *International Journal of Agricultural and Biological Engineering*, 6(2), 107-115.
<https://doi.org/10.3965/ijabe.20130602.0012>.
 22. Cahyo AN, Sahuri S, Nugraha IS, Ardika R (2019) Cocopeat as soil substitute media for rubber (*Hevea brasiliensis* Müll. Arg.) planting material. *Journal of Tropical Crop Science*, 6(1), 24-29.
<https://doi.org/10.29244/jtcs.6.01.18-29>.
 23. Hong S, Lee SM, Lee EY (2011) Bioremediation efficiency of oil-contaminated soil using microbial agents. *Korean Journal of Microbiology and Biotechnology*, 39(3), 301-307.
 24. Lee JJ, Kim YS, Ham SK, Lee CE, Lee GJ (2015) Growth

- and quality improvement of creeping bentgrass by two fertilizers containing *Trichoderma* species. *Weed and Turfgrass Science*, 4(3), 249-255.
<https://doi.org/10.5660/WTS.2015.4.3.249>.
25. Lastdrager J, Hanson J, Smeekens S (2014) Sugar signals and the control of plant growth and development. *Journal of Experimental Botany*, 65(3), 799-807.
<https://doi.org/10.1093/jxb/ert474>.
26. Yao H, Bowman D, Shi W (2011) Seasonal variations of soil microbial biomass and activity in warm- and cool-season turfgrass system. *Soil Biology & Biochemistry*, 43, 1536-1543.
<https://doi.org/10.1016/j.soilbio.2011.03.031>.
27. Kussow WR, Soldat DJ, Kreuser WC, Houlihan SM (2012) Evidence, regulation, and on sequences of nitrogen-driven nutrient demand by turfgrass. *International Scholarly Research Network Agronomy*, 359284, 1-9.
<https://doi.org/10.5402/2012/359284>.
28. Kim YS, Lee CE, Ham SK, Lee GJ (2016) Growth of creeping bentgrass by application of compound fertilizer containing microbes. *Weed and Turfgrass Science*, 5(1), 42-50.
<https://doi.org/10.5660/WTS.2016.5.1.42>.