

Research Article



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건조, 강우, 저온 환경에서 관상용 억새 원예품종의 생장 반응과 경관의 지속성

김기동¹, 김영선², 이정호^{3*}

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Growth Response and Durability of Landscape of Ornamental *Miscanthus sinensis* Cultivars to Drought, Rain Fall and Low Temperature Condition

Ki-Dong Kim¹, Young-Sun Kim² and Jeong-Ho Lee^{3*} (¹Department of Golf Course Landscaping Business, Nousbo ENG, Yongin 17035, Korea, ²Department of Horticultural Science, College of Natural and Life Sciences, Daegu University, Gyeongsan 38453, Korea, ³Department of Golf Course Management, Korea Golf University, Hoengseong 25249, Korea)

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ORCID

Ki-Dong Kim

<https://orcid.org/0000-0002-3266-4683>

Young-Sun Kim

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

Jeong-Ho Lee

<https://orcid.org/0009-0001-4073-010X>

Abstract

Miscanthus sinensis Andersson (Poaceae) cultivars exhibit excellent visual appeal as ornamental grasses and adapt well to diverse environmental conditions. This study focused on assessing the growth response and landscape durability of seven popular *Miscanthus* cultivars ('Gold Breeze', 'Strictus', 'Morning Light', 'Variegatus', 'Gracillimus', 'Kleine Fontäne', 'Common') under drought, rainfall and low temperature condition. The test cultivars were transplanted and cultivated on research plots in 2013, with data collected from June 2017 to February 2018. Plant materials were categorized into three types based on the amount of the water lost; group I ('Kleine Fontäne', 'Variegatus', 'Strictus'), experiencing the most significant water loss; group II

('Common', 'Gracillimus'); and group III ('Gold Breeze', 'Morning Light') where the least water loss occurred. The drought resistance index (DRI) remained low as water shortage conditions persisted. The lodged angle underwent more pronounced changes in reproductive growth stage than in vegetative growth stage, notably decreasing after heading. Discoloration patterns were classified into two types: group I ('Common', 'Gold Breeze', 'Kleine Fontäne', 'Strictus') and group II ('Gracillimus', 'Morning Light', 'Variegatus') based on the periods of peak duration.

Key words: Discoloration, Drought resistance index, Lodged angle, Mean weekly discoloration, *Miscanthus sinensis*, Poaceae

서론

(transition zone)

*Corresponding author: Jeong-Ho Lee

Phone: +82-33-810-1066; Fax: +82-33-810-1001;

E-mail: teetogreen@naver.com

재료 및 방법

[1]. 가 가 공시 재료 (Miscanthus sinensis) 7 (Table 1). (ornamental grasses) [2-6]. (United States Department of Agriculture, USDA) Natural Resources Conservation Service Plant Database Missouri Botanical Garden (MBG) Plant Finder, The Encyclopedia of Grasses for the Livable Landscapes, (Korea Forest Service, KFS) (soil texture) [7,8]. 5가 [9-11]. (Korea National Arboretum, KNA) (Miscanthus spp.), 가 (Pennisetum spp.) 가 (Korean Plant Names Index, KPNI) C₄ type [21] 가 .

14]. 가 가 [12- 건조 환경과 생장 반응 2017 7 9 (even span greenhouse) 3 2017 7 300 mm, 300 mm [15] 10-15 가 . 1 8 15 가 (field capacity) 39 (TDR 150, Spectrum Technologies, Inc., Plainfield, IL, USA) (permanent wilting point) 4 가 가 phase 1 (), phase 2 (1/4), phase 3 (1/4-1/2), phase 4 (2/3), phase 5 () 5 . DRI Nilsen[20] (discoloration) 7가 (drought resistance index, DRI), (lodged angle, LA), (lodging rate, LR), 가(visual rating), (mean weekly discoloration, MWD) .

Table 1. Height, leaf pattern, growth habit and overall form of 7 *Miscanthus sinensis* cultivars in the study

Cultivar	Height (m)	Leaf pattern	Growth habit	Overall form
‘Gold Breeze’	1.2-1.5	Zebra-stripe ¹⁾	Short rhizomatous ⁴⁾	Upright arching ⁵⁾
‘Strictus’	1.2-2.7			
‘Morning Light’	1.2-1.8	Stripe ²⁾		
‘Variegatus’	1.5-2.7			
‘Gracillimus’	1.2-2.1	Normal ³⁾		
‘Kleine Fontäne’	0.9-1.2			
‘Common’	1.2-2.1			

¹⁾Horizontal bands of yellow variegation.

²⁾Longitudinally striped with leaf vein of light golden-yellow or white variegation.

³⁾Green color without variegation.

⁴⁾Clumps slowly expand in circumference by short rhizomes, but typically retain tight clump shape.

⁵⁾Foliage ascends stiffly and vertically, then falls in a fountain of arcs from the top. ‘Gold Breeze’ and ‘Strictus’ are more upright than other cultivars.

DRI '1'
DRI

$$DRI = Lwi / LW$$

Lwi: leaf width of after drought stress

LW: leaf width of normal growth

생장단계별 강우에 의한 도복각 변화와 도복률

2017 6 2018 2 4 LA

(exterior angle)
50 cm × 50 cm

1 가

LR

9 10

phase 1 (LA 0-30°), phase 2

(31-60°) phase 3 (61-90°) 3

$$LR = (ni / N) \times 100$$

ni: number of lodged plant

N: total number of plant

저온 환경에 대한 엽색 퇴화

2017 9 12 2 , 4 Na-

national Turfgrass Evaluation Program (NTEP)

가 NTEP scale 1 (equaling straw brown or no color retention) 9

(equaling dark green)

가

가 (Fig. 1). MWD scale

NTEP scale

scale '1' '0' , scale

'9' '8'

$$MWD = 8 / T$$

8: calibrated maximum scale (constant)

T: total discoloration period (weeks)

A



B



Fig. 1. Scale of winter discoloration. Discoloration evaluation method was applied to the National Turfgrass Evaluation Program (NTEP). It was evaluated with a 1 to 9 visual rating scale of 1=straw brown (A 'Strictus') and 9=completely green (B 'Strictus') color based on plot color not genetic color.

경관 지속성

기상데이터 및 유지 관리

2017 7 2018 2

(monthly mean temperature, MMT),

(monthly mean minimum temperature,

MMmT) (monthly cumulated precipitation, MCP) (Fig. 2).

(soil texture), pH, (electronic conductivity), (organic matter) Tyurin ,

(cation exchange capacity) 1.0 M NH₄OAc (pH 7.0) , (NO₃), (available phosphate, Av-P₂O₅) Lancaster , (K⁺)

1.0 M NH₄OAc (pH 7.0)

(ICP-OES, GBC, Integra XL Dual, Australia)

(Table 2).

2013

3 (shoot)가

20 cm

[22-24].

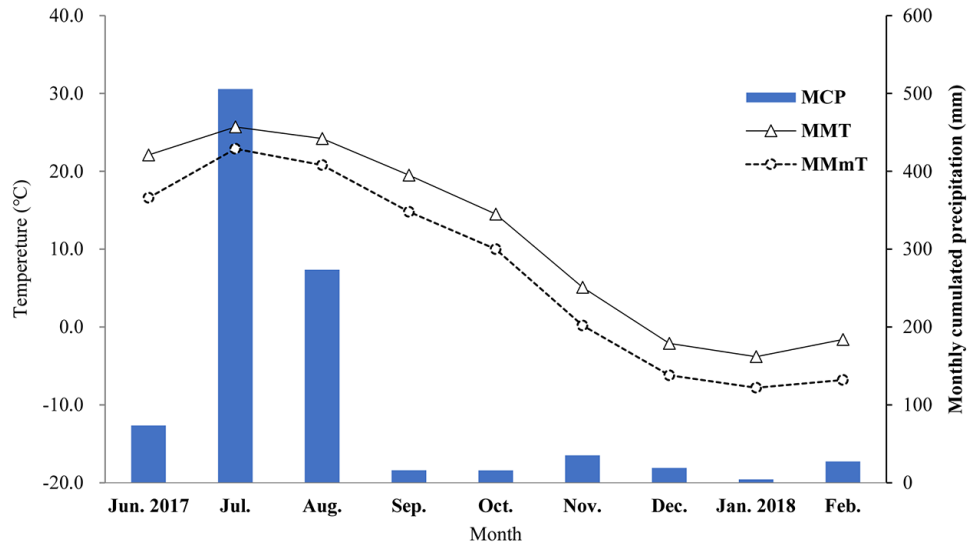


Fig. 2. Weather information during the test period. Monthly mean temperature (MMT), monthly mean minimum temperature (MMmT) and monthly cumulated precipitation (MCP) at the research field from June 2017 to February 2018 during the test period.

Table 2. Physicochemical properties of soil used in this experiment

Soil texture	pH (1:5)	EC (1:5) (dS/m)	OM (%)	CEC (cmol _c /kg)	Av. P ₂ O ₅ (mg/kg)	NO ₃ (mg/kg)	K ⁺ (cmol _c /kg)
Sandy loam	6.5	0.022	3.0	15.4	430.6	160.3	0.2

통계 분석

Statistical Analysis System (SAS) 9.4 ANOVA

(Duncan's multiple range test) 5%

I, group II phase 1 phase 4 group III group I, group II phase 4 group III (Table 4).

가 5% 가 가

결과 및 고찰

건조 환경에서의 생육

(Table 3). 8 15 26.7 ('Strictus') - 28.4 ('Gold Breeze') %

group I ('Kleine Fontäne', 'Variegatus', 'Strictus'), group II ('Common', 'Gracillimus') group III ('Gold Breeze', 'Morning Light') 3가 Group I ('Kleine Fontäne', 'Variegatus', 'Strictus') 12 8 27 (phase 5) group II ('Common', 'Gracillimus') 16 8 31 , group III ('Gold Breeze', 'Morning Light') 24 9 8 가 group

가 가 가 [6, 24-26]. 가 가 가 DRI가 DRI [27-29]. *M. sinensis* cultivars 'Zebrinus' > 'Gracillimus' > 'Variegatus' > 'Common' [30]. 'Gracillimus' 'Variegatus' 'Common' (*M. sinensis* Andersson) 'Variegatus' *M. sinensis* Andersson 가 가 가 [31-35].

Table 3. Changes of soil water content under water cut-off condition in the green house (August 2017, n=3)

Cultivar	Soil water content ¹⁾ (%)							
	Aug. 15 ²⁾	Aug. 19	Aug. 23	Aug. 27	Aug. 31	Sep. 4	Sep. 8	Sep. 12
'Gold Breeze'	28.4	21.2	15.8	9.4	6.7	3.7	2.0	0.0
'Strictus'	26.7	13.1	4.4	2.6	0.0	- ³⁾	-	-
'Morning Light'	27.8	21.4	14.1	6.5	3.1	1.2	0.0	-
'Variegatus'	27.9	12.6	5.4	1.6	0.0	-	-	-
'Gracillimus'	27.3	16.1	8.8	3.7	1.5	0.0	-	-
'Kleine Fontäne'	28.1	10.1	3.3	1.5	0.0	-	-	-
'Common'	27.6	16.2	11.9	5.8	2.2	1.7	0.0	-

¹⁾It was measured by soil moisture meter (Field Scout™ TDR 150).

²⁾Field capacity.

³⁾Not measured after water contents 0.0%.

Table 4. Wilting rate and drought resistance index (DRI) of 7 *Miscanthus sinensis* cultivars under water cut-off condition (August 2017, n=3)

Cultivar	Wilting rate ¹⁾ (DRI) ²⁾							
	Aug. 15	Aug. 19	Aug. 23	Aug. 27	Aug. 31	Sep. 4	Sep. 8	Sep. 12
'Gold Breeze'	1 (0.92)	1 (0.92)	1 (0.93)	1 (0.93)	1 (0.93)	3 (0.61)	4 (0.27)	5 (0.15)
'Strictus'	1 (0.90)	1 (0.90)	1 (0.90)	5 (0.20)	- ³⁾	-	-	-
'Morning Light'	1 (0.84)	1 (0.85)	1 (0.85)	1 (0.85)	3 (0.62)	4 (0.37)	5 (0.22)	-
'Variegatus'	1 (0.94)	1 (0.94)	1 (0.94)	5 (0.18)	-	-	-	-
'Gracillimus'	1 (0.90)	1 (0.91)	1 (0.91)	1 (0.92)	5 (0.26)	-	-	-
'Kleine Fontäne'	1 (0.92)	1 (0.92)	1 (0.92)	5 (0.22)	-	-	-	-
'Common'	1 (0.94)	1 (0.94)	1 (0.95)	1 (0.95)	4 (0.26)	5 (0.19)	-	-

¹⁾Visual rating of wilting rate is based on phase 1 to 9 rating scale by Rural Development Administration (2012). 1=normal growth, 2=1/4 wilted, 3=1/4-1/2 wilted, 4=more than 2/3, 5=mostly wilted.

²⁾DRI = Lwi/LW. Lwi=leaf width after drought stress (cm), LW=leaf width on normal growth (cm).

³⁾Not measured after phase 5.

40°C pot 'Kleine Fontäne' 7 가 7 26
 [36-38]. , (Fig. 3, Table 5). 8 6 51.3°
 DRI 10 3 . 'Strictus'
 가 'Common'
 (Fig. 3, Table 5). 'Strictus' 'Common'
 생육단계별 강우 시 역세의 도복각 9 가 9 12 9 20
 Kim et al.[39] 10 13
 'Variegatus'
 가 (Fig. 4, Table 5).
 6 2
 78.8-80.0° [41-43], [44,45]
 가 'Variegatus' 가
 (Fig. 3-5, Table 5). 가
 가
 ('Kleine Fontäne', 'Common', 'Strictus') 9 12 20 40°
 ('Variegatus', 'Gracillimus', 'Morning Light') 9 가
 [42] 가

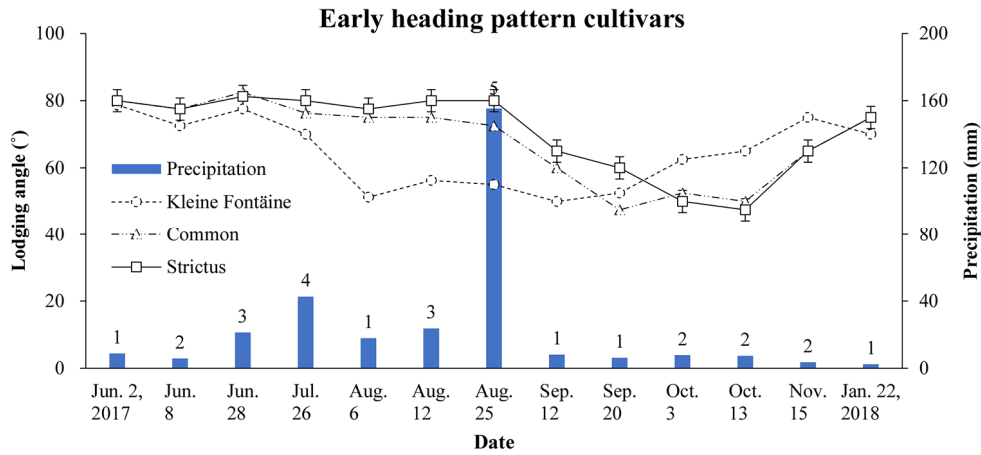


Fig. 3. Changes of lodged angle of 3 early heading cultivars ('Kleine Fontäne', 'Common', 'Strictus'). It shows that more lodged in the reproductive growth stage than vegetative growth stage. The numbers above histogram indicate the date of successive precipitation days.

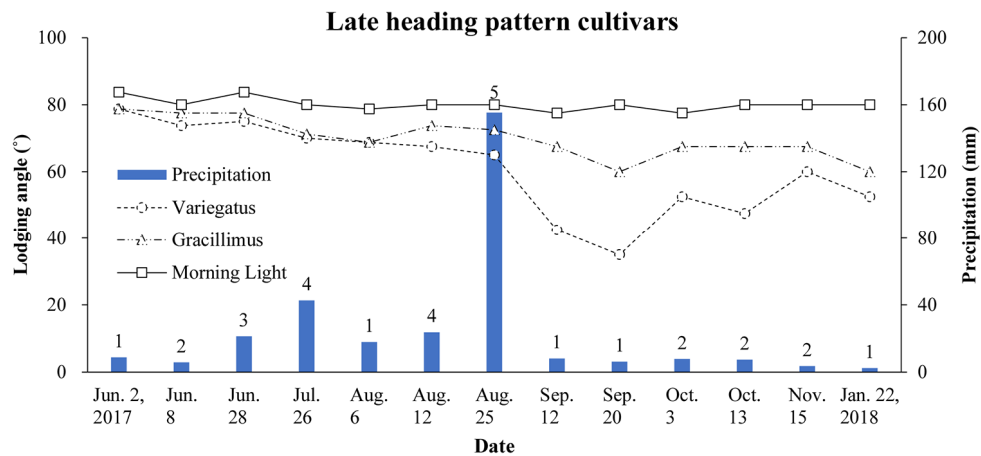


Fig. 4. Changes of lodged angle on the late heading cultivars ('Variegatus', 'Gracillimus', 'Morning Light'). It shows that more lodged in the reproductive growth stage than vegetative growth stage. 'Morning Light' was kept its overall form during test period. The numbers above histogram indicate the date of successive precipitation days.

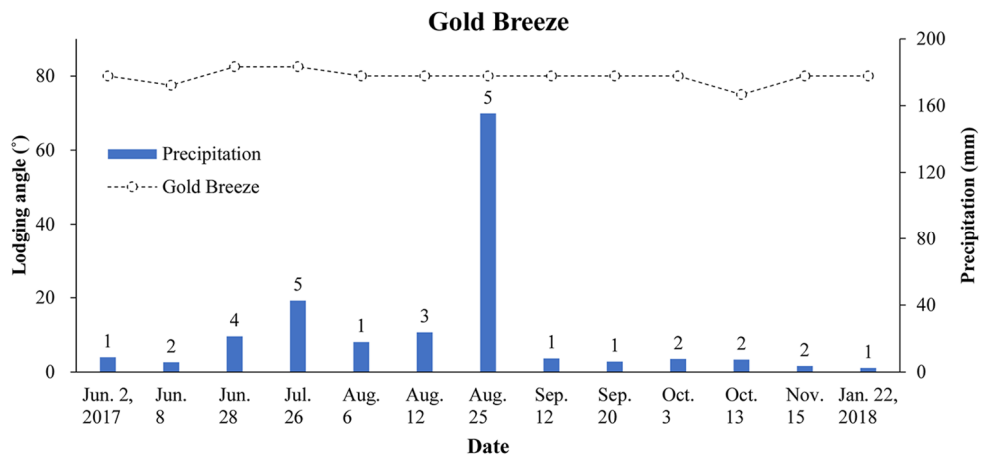


Fig. 5. Changes of lodged angle on 'Gold Breeze'. It did not bloom and showed that kept its overall form during test period. The numbers above histogram indicate the date of successive precipitation days.

Table 5. Chances of lodged angle on 7 *Miscanthus sinensis* cultivars after rainfall (n=4)

Cultivar	Lodged angle ¹⁾ (°)												
	2017											2018	
	Jun. 2	Jun. 8	Jun. 28	Jul. 26	Aug. 6	Aug. 12	Aug. 25	Sep. 12	Sep. 20	Oct. 3	Oct. 13	Nov. 15	Jan. 22
'Gold Breeze'	80.0	77.5	82.5	82.5	80.0	80.0	80.0	80.0	80.0	80.0	75.0	80.0	80.0
'Strictus'	80.0	77.5	81.3	80.0	77.5	80.0	80.0	65.0	60.0	50.0	47.5	65.0	75.0
'Morning Light'	83.8	80.0	83.8	80.0	78.8	80.0	80.0	77.5	80.0	77.5	80.0	80.0	80.0
'Variegatus'	78.8	73.8	75.0	70.0	68.8	67.5	65.0	42.5	35.0	52.5	47.5	60.0	52.5
'Gracillimus'	78.8	77.5	77.5	71.3	68.8	73.8	72.5	67.5	60.0	67.5	67.5	67.5	60.0
'Kleine Fontäne'	78.8	72.5	77.5	70.0	51.3	56.3	55.0	50.0	52.5	62.5	65.0	75.0	70.0
'Common'	80.0	77.5	82.5	76.3	75.0	75.0	72.5	60.0	47.5	52.5	50.0	65.0	75.0

¹⁾Exterior angle of stem to the ground. It measured after rainfall throughout 1 day and excluded completely lodged plants.

'Gracillimus' 가

'Variegatus' (Fig. 4, 생식생장단계에서 도복률

Table 5). 'Morning Light' 가 가

가 (Fig. 4, Table 5). , 'Gold Breeze' 가 가

가 가 (Fig. 5, Table 5). 10 9 10 LR

가 (Table 6). 'Morning Light' 'Gold Breeze' 5

가 가 8 25 . 9 20

'Kleine Fontäne' 1 'Kleine Fontäne' 4 'Common', 'Variegatus', phase 1

Fontäne' 6 8 25 가 'Kleine Fontäne' 30% 'Strictus', 'Kleine Fontäne' 10 13

Fontäne' 가 8 25 phase 2 'Common', 'Variegatus'

8 6 phase 1 10% 20%

가 가 가

가 [49-52], [40]. 가

가 [46]. 가 'Morning Light' 'Gold Breeze'

가 7-9 가 'Gold Breeze' 가

가 가 , 'Morning Light' 5 가

가 가

[47]. (M. sacchariflous x M. sinensis) Miscanthus x giganteus 저온 환경에서 잎의 변색

(M. sinensis) M. sinensis 가

가 [48]. M. sinensis [53].

'Kleine Fontäne', 'Gracillimus', 'Variegatus' 가 가

Table 6. Lodging rate (LR) of 7 *Miscanthus sinensis* cultivars in reproductive growth stage (n=10)

Cultivar	LR ¹⁾ (%)								
	Sep. 20 2017			Oct. 3			Oct. 13		
	Phase 1 ²⁾	Phase 2 ³⁾	Phase 3 ⁴⁾	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
'Gold Breeze' ⁵⁾	0	0	100	0	0	100	0	0	100
'Strictus'	30	60	10	0	40	60	0	100	0
'Morning Light'	0	0	100	0	0	100	0	0	100
'Variegatus'	30	60	10	30	70	0	10	80	10
'Gracillimus'	10	60	30	0	30	70	0	20	80
'Kleine Fontäne'	30	50	20	20	50	30	0	20	80
'Common'	30	50	20	20	60	20	20	60	20

¹⁾LR = (ni/N) × 100. ni=number of lodged plant, N=total number of plant.

²⁾Lodged angle 0-30°.

³⁾Lodged angle 30-60°.

⁴⁾Lodged angle 60-90°.

⁵⁾'Gold Breeze' did not bloom during test period.

가 [54]. 'Common', 'Kleine Fontäne' 9 22, 'Gold Breeze', 'Strictus', 'Morning Light', 'Variegatus', 'Gracillimus' 10 6 (Table 7). ('Common', 'Kleine Fontäne', 'Strictus') ('Gracillimus', 'Morning Light', 'Variegatus') 2가 9 22 10 6 scale 8.0-7.0 10 20 scale 5.8-4.5, 'Strictus' 가 'Common' 12 1 scale 1 15°C (Table 7). 'Kleine Fontäne' 가 [55] 9 10 (Table 7). 11 3 scale 3.5-2.0 11 17 scale 4.5 ('Common') - 3.5 ('Stictus') scale 7.0 ('Morning Light', 'Variegatus') - 6.0 ('Gracillimus') MWD

Table 7. Discoloration (scale), total period, peak duration and mean weekly discoloration (MWD) of 7 *Miscanthus sinensis* cultivars in 2017 test (n=4)

Cultivar	Discoloration (scale 1-9) ¹⁾						Period ²⁾ (weeks)	Peak duration ³⁾	MWD ⁴⁾ (scale)
	Sep. 22	Oct. 6	Oct. 20	Nov. 3	Nov. 17	Dec. 01			
'Gold Breeze'	9.0 a ⁵⁾	7.5 bc	2.8 d	2.0 e	1.0 d	- ⁶⁾	6	Oct. 6-20	1.3 a
'Strictus'	9.0 a	7.5 bc	4.5 c	3.5 d	1.5 cd	1.0a	8	Oct. 6-20	1.0 b
'Morning Light'	9.0 a	8.0 ab	7.3 a	7.0 a	3.5 a	1.0a	8	Nov. 3-17	1.0 b
'Variegatus'	9.0 a	8.5 a	7.3 a	7.0 a	2.0 bc	1.0a	8	Nov. 3-17	1.0 b
'Gracillimus'	9.0 a	8.5 a	6.3 b	6.0 b	2.0 bc	1.0a	8	Nov. 3-17	1.0 b
'Kleine Fontäne'	8.3 b	8.0 ab	5.8 b	4.0 cd	2.3 b	1.0a	10	Oct. 6-20	0.8 c
'Common'	8.0 b	7.0 c	4.8 c	4.5 c	1.5 cd	1.0a	10	Nov. 3-17	0.8 c

¹⁾Visual rating of cold tolerance is based on discoloration. 1 to 9 rating scale by National Turfgrass Evaluation Program (2017). 1=straw brown and 9=completely green based on plot color not genetic color.

²⁾Total period of weeks from when start discoloration till termination.

³⁾Period of the highest reduced discoloration scale.

⁴⁾MWD = 8/T. 8=constant (maximum scale), T=total green up period (weeks).

⁵⁾Different letters in each row indicate significant difference by Duncan's multiple range test at p<0.05.

⁶⁾Not evaluated after scale 1 (straw brown).

10.0°C, 11 0.2 24 4% 가
 °C C₄ type [Arundinella hirta var. ciliate 77.5-83.8° 77.5-80.0°
 Koidz, Panicum virgatum L., Pennisetum alopecuroides (L.) Spreng, Zoysia japonica] 가 10°C 11
 10-11 12 (Fig. 4, Table 8).
 [10,56,57]. 'Variegatus' 8
 12 6% 가
강우, 건조, 저온 환경 조건에서 경관 유지 특성
 (Table 8). 45.0-78.8° 35.0-60.0°
 'Gold Breeze' 8 가 10
 24 4% 가 11 (Fig. 4, Table 8).
 75.0-82.5° 10 'Gracillimus' 8
 가 11 16 4% 가 68.8-
 (Fig. 5, Table 8). 'Strictus' 8 12 78.8°
 'Strictus' 8 5% 가 60.0-67.5° 10
 77.5-81.3° 11
 47.5-75.0° 12 (Fig. 3, Table 8).
 10 'Kleine Fontäne' 8
 11 12 (Table 8). 4% 가
 (Fig. 3, Table 8).
 'Morning Light' 8 72.5-78.8°

Table 8. Durability of landscape on 7 Miscanthus sinensis cultivars under environmental stress

Cultivar	Drought		Lodging				Discoloration	
	UID ¹⁾ (day)	PWP ²⁾ (%)	LA ³⁾ range (°)		Occurrence of lodging ⁴⁾		Peak duration ⁵⁾	MWD ⁶⁾
			VGS ⁷⁾	RGS ⁸⁾	VGS	RGS		
'Gold Breeze'	24	3.7	75.0-82.5	- ⁹⁾	X	-	Oct. 6-20	F
'Strictus'	12	4.4	77.5-81.3	47.5-75.0	X	△	Oct. 6-20	M
'Morning Light'	24	3.1	77.5-83.8	77.5-80.0	X	X	Nov. 3-17	M
'Variegatus'	12	5.4	45.0-78.8	35.0-60.0	△	○	Nov. 3-17	M
'Gracillimus'	16	3.7	68.8-78.8	60.0-67.5	X	△	Nov. 3-17	M
'Kleine Fontäne'	12	3.3	72.5-78.8	51.3-75.0	X	△	Oct. 6-20	S
'Common'	16	2.2	72.5-82.5	47.5-75.0	X	○	Nov. 3-17	S

¹⁾Unirrigated dates. Total period from phase 1 (normal growth) to phase 5 (almost wilted) to water stress.
²⁾Permanent wilting point. Soil water contents of phase 5 (almost wilted).
³⁾Lodged angle. Exterior angle of stem.
⁴⁾Occurrence of lodged plant from phase 1 (lodged angle 0-30°) to phase 3 (lodged angle 61-90°). X=phase 3, △=phase 2 and ○=phase 1.
⁵⁾Period of the highest reduced discoloration scale.
⁶⁾MWD = 8/T. 8=calibrated maximum scale and T=total discoloration period.
⁷⁾Vegetative growth stage.
⁸⁾Reproductive growth stage.
⁹⁾'Gold Breeze' did not bloom during the test period.

51.3-75.0°
 9
 10
 12 (Fig. 3, Table 8).
 'Common' 8
 16 3% 가
 72.5-82.5°
 47.5-75.0°
 가 9
 11
 11 12
 (Fig. 3, Table 8).

결론

가 가
 (*Miscanthus sinensis* Andersson) 7가
 ('Gold Breeze', 'Strictus', 'Morning Light', 'Variegatus',
 'Gracillimus', 'Kleine Fontäne', 'Common')
 2013 2017 6
 2018 2 가
 가
 group I ('Kleine Fontäne', 'Varie-
 gatus', 'Strictus'), group II ('Common', 'Gracillimus')
 group III ('Gold Breeze', 'Morning Light') 3가
 가 'Morning
 Light', 'Gold Breeze' 5
 'Variegatus'
 가
 group I ('Common', 'Gold Breeze', 'Kleine
 Fontäne', 'Strictus') group II ('Gracillimus', 'Morning
 Light', 'Variegatus') 2가

Note

The authors declare no conflict of interest.

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