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Potassium Rate and Mowing Height for Kentucky Bluegrass Growth

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ABSTRACT. Potassium is well-known to improve turfgrass tolerance to environmental stresses such as low temperature and drought stress. Low mowing height reduces leaf area of turfgrass that is main place for photosynthesis and carbohydrate production. Closely-mowed turf would suffer from summer decline by low level of carbohydrate resulted from low photosynthesis of reduced leaf area. The objective of the study is to investigate K rate and mowing height for Kentucky bluegrass. The K rate treatments were 5, 10, and 20 g K_2O m^{-2} for the low, medium and high K rates, respectively. The bi-weekly mowing treatment was made for treatments. Mowing was implemented at 40 and 100 mm using a rotary mower. Regardless K rates, the high mowing height would be required when the air temperature is higher than 28.5°C and high turfgrass quality of Kentucky bluegrass is needed. When the air temperature is optimal for cool-season grass, the high mowing height and the low K rate is needed for the root length of Kentucky bluegrass.

***Key words*:** Kentucky bluegrass, Mowing Height, Potassium, Summer decline

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Introduction

Summer decline of cool-season grasses is one of the critical factors to alleviate turf quality. Low mowing height is a major factor of summer decline to induce a reduction in soil oxygen which cause to lower turf quality and accelerate turf loss for cool-season grasses. It also reduces leaf area of turfgrass that is main place for photosynthesis and carbohydrate production. Closely-mowed turf would suffer from summer decline by low level of carbohydrate resulted from low photosynthesis of reduced leaf area. Turfgrass at mowing height below tolerance range get more possibility of weed invasion while turfgrass become excessive growth, more disease outbreak and thicker thatch at mowing height above tolerance range. Fagerness and Yelverton (2001) reported that decreasing mowing heights reduced 36% root growth in 'Penncross' creeping bentgrass (*Agrostis stolonifera* L.). Hoyle (2009) investigated the effect of mowing height on large crabgrass (*Digitaria sanguinalis* L.) infestation in tall fescue (*Festuca arundinacea* Schreb.) and found that large crabgrass incidence was increased about 93% when mowing height decreased from 10.2 to 2.5 cm. Voigt et al. (2001) found that crabgrass infestation was increased to 37% when tall fescue at 2.5 cm and increased to 8% where tall fescue mowed at 5.1 to 7.6 cm. Tucker et al. (2006) investigated the effects of mowing height, N rate, and biostimulant on root growth of 'TifEagle' bermudagrass (*Cynodon dactylon* L.). They found that turf quality, root surface area, and root length density were improved when mowing height was increased from 3.2 mm to 4.8 mm.

Heat stress which is another factor of summer decline can be reduced with high rate of potassium (K) application when nitrogen (N) is sufficiently applied because high rate of K and N increase rooting depth which enhance the drought tolerance and turgor pressure which reduce wilting injury (Pellet and Roberts, 1963). Potassium which is an essential nutrient for turfgrass growth is required in the greatest quantity with N and well-known to enhance turfgrass ability to tolerate environmental stresses. Webster and Ebdon (2005) investigate the cold tolerance of perennial ryegrass (*Lolium perenne* L.) treated with N and K during deacclimation in late winter and early spring. They found that the 441 kg ha^{-1} yr^{-1} of K application reduced snow mold (*typhula blight*) severity about 9.3% compared to the 49 kg ha^{-1} yr^{-1} of K application on perennial ryegrass. Hurto and Troll (1980) evaluated low temperature hardiness of 'Manhattan' perennial ryegrass and found that application of high K level increase maximum tiller survival with higher tissue K levels. Miller and Dickens (1997) reported that bermudagrass applied by 49 or 98 kg K ha^{-1} was recovered from drought stress faster than bermudagrass with no K treatments. The previous research stated that high K^+/Na^+ ratio in growing tissue makes plants having more salt tolerance in red fescue and perennial ryegrass (Krishnan and Brown, 2009). In addition to cold, drought, salt and disease tolerance by increasing K levels, many previous research reported the increased ability of turfgrass tolerances with K application under environmental stress such as wear stress (Shearman and Beard, 1975; Carrow and Wiecko, 1989) and stomatal regulation (Wallingford, 1980). However, there were inverse results reported regarding no K effects to grass growth under environmental stress. Cook and Duff (1976) found no K effects on freezing tolerance of tall fescue. Dest and Guilliard (2001) found no correlation between K application and moisture stress. Thus, additional research is needed to scrutinize the effects of K on turfgrass growth under various environmental stresses.

Controlling mowing height is related to turf quality, root growth and weed invasion. Research data of K effects to turfgrass growth have been reported as inconsistent results. This suggests that the influence with K rate with different mowing height to turfgrass is not clearly understood. Therefore, the objective of this study is to investigate K rate and mowing height for Kentucky bluegrass under summer decline period.

Materials and Methods

Research was initiated at the Hoseo Turfgrass Research Center on the campus of Hoseo University in Asan, Chungnam, Korea. Research plot for the study was established for 'midnight' Kentucky bluegrass (*Poa pratensis* L.) at October, 2014. Each plot size for the study was 0.8 by 1.2 m. The first application was made in August 10, 2015. After the first application, irrigation was applied approximately every other day unless precipitation made irrigation unnecessary. The 5 g N m^{-2} were applied to entire plot area for turf growth before the initiation of the study. A slow-release N (the Endure, 15-15-15, BEST, California, USA) was used as a N source. A potassium sulfate (0-0-50, POONGNONG Inc., Seoul, Korea) was applied for the K treatments. The K rate treatments were 5, 10, and 20 g K_2O m^{-2} for the low, medium and high K rates, respectively. The bi-weekly mowing treatment was made for treatments. Mowing height were 40 and 100 mm using a rotary mower (GXV160, HONDA, Georgia, USA). Seasonal turf color and quality ratings are measured for entire research plot (NTEP, 2011). Turfgrass color was measured by an index of damage caused by disease or insect pests, nutrient deficiency or environmental stress. Turfgrass color was visually rated on a scale of 1 to 9 (1=straw brown, 6=acceptable, and 9=dark green) every two weeks. Turfgrass quality was measured by an index of turf density, leaf texture, disease resistance, mowing qualities, and stress tolerance including several stresses during winter (Beard, 1973; Turgeon, 2008). Turfgrass quality was visually rated on a scale of 1 to 9 (1=poor, 6=acceptable, and 9=best) every two weeks. Root length was measured for the growth of Kentucky bluegrass on October 15, October 22, and November 5 which are 76, 83 and 97 days after the first treatment, respectively. Three measurements were made for each plot and averaged for the root length. The experimental design was a randomized complete-block design with three replications. Analysis of variance (ANOVA) was performed on transformed data using Statistical Analysis Systems design (SAS Institute Inc., 2001). Treatment differences were analyzed by the Proc Mixed procedure. When appropriate, mean separations were performed by Fischer's protected least significant difference (LSD) at a 0.05 probability level. All statistical analyses were analyzed by SAS.

Results and Discussion

There were no two-way interactions between K rate and mowing height for turfgrass color and quality (Table 1). Significant differences by mowing height main effects were found on turfgrass color (Table 2). For all of the sampling dates, the 100 mm mowing height had higher turfgrass color rating than the 40 mm mowing height on 8 of 11 rating dates. Similar result was reported from the previous research (Salaiz et al., 1995) who found that the color of creeping bentgrass was improved when the mowing height was increased from 3.2 to 4.8 mm. The 40 mm mowing height had lower turfgrass color rating than an acceptable color rating of six on 4 of 11 rating dates. The turfgrass color ratings on all sampling dates with the 100 mm mowing height were greater than six throughout the research period except November 5. When the range of the maximum air temperature was 28.5°C to 30.4°C which is higher temperature than the optimal temperature range for cool-season grasses, high mowing height had 9% to 25% greater turfgrass color than the 40 mm mowing height. Only one day among these sampling dates had the optimal temperature range for cool-season grasses which is September 12. However, no significant differences were found between the 100 mm and the 40 mm mowing heights when the range of the maximum air temperature was 24.3°C to 24.4°C. Beard (1973) stated that the optimal temperatures for cool-season grasses are 15.6°C to 23.9°C for shoot growth and 10.0°C to 18.3°C. When the range of the maximum air temperature is close to the optimal temperature for shoot growth of cool-season grasses, turfgrass color was not influenced by mowing height based on the result of the study. When the maximum air temperature was 19.4°C, the low and the 100 mm mowing height had lower turfgrass color rating than an acceptable

Table 1. Analysis of variance for Kentucky bluegrass color and quality of Kentucky bluegrass.

Source	Aug. 10	Aug. 20	Aug. 27	Sep. 4	Sep. 12	Sep. 22	Sep. 30	Oct. 6	Oct. 15	Oct. 22	Nov. 5
	------ Turf color ------										
Mowing height (MH)	**	**	**	**	**	**	NS[Z]	NS	NS	**	*
K rate (KR)	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
MH × KR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	------ Turf quality ------										
Mowing height (MH)	**	**	**	**	**	**	*	**	**	**	*
K rate (KR)	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS
MH × KR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]NS indicates not significant at *P*=0.05.
*, **indicates significance at *P*=0.05 and *P*=0.01, respectively.

Table 2. Mean Kentucky bluegrass color for mowing height main effect of Kentucky bluegrass.

Mowing height[w]	Aug. 10	Aug. 20	Aug. 27	Sep. 4	Sep. 12	Sep. 22	Sep. 30	Oct. 6	Oct. 15	Oct. 22	Nov. 5
	------ Turfgrass color ------										
40	6.0[x] b[y]	6.7b	6.9b	6.4b	5.9b	7.1b	7.1	7.0	5.6	4.6b	5.0b
100	8.0a	8.9a	8.0a	7.9a	7.3a	7.8a	7.3	7.3	5.7	6.1a	5.7a
	------ Daily air temperature (°C) ------										
Min. Temp.	21.8[z]	22.7	18.8	18.6	15.0	14.7	17.6	7.7	9.2	10.7	6.6
Avg. Temp.	25.1	24.3	23.3	23.9	18.0	21.4	20.6	15.8	15.7	16.8	11.6
Max. Temp.	29.4	28.5	29.0	30.2	22.4	30.4	24.4	25.6	24.3	23.9	19.4

[w]The unit of mowing height was millimeter (mm).
[x]Mean turfgrass color was measured by visual evaluation using 1 to 9 scale (1=straw green, 6=acceptable, and 9=dark green).
[y]Means in a column with the same upper case letters or no letters are not significantly different according to Fisher's LSD (*P*=0.05).
[z]Daily air temperature is not statistical data but reference data by weather-i.

color rating of six.

There were significant differences between the 40 mm and the 100 mm mowing heights for turfgrass quality (Table 3). The 100 mm mowing height had greater turfgrass quality rating than the 40 mm mowing height throughout the study. The previous studies have also reported reduced turfgrass quality with the low mowing height (Carrow, 1996; Beard, 1997). The 100 mm mowing height had greater turfgrass quality rating than an acceptable color rating of six throughout the study except October, 22. The 40 mm mowing height had lower turfgrass quality rating than an acceptable color rating of six on 5 of 11 rating dates. When the range of maximum air temperature was 28.5°C to 30.2°C which are higher temperature than the optimal temperature range for cool-season grasses, the 100 mm mowing height had 13.8% to 26.3% greater turfgrass quality rating than the 40 mm mowing height. The 100 mm mowing height had 6.7% to 19.2% greater turfgrass quality than the 40 mm mowing height when the range of maximum air temperature was 19.4°C to 25.6°C which are the optimal temperature or close to optimal temperature range for cool-season grasses. Liu and Huang (2003) reported the positively related results on creeping bentgrass and found that high mowing height had greater turfgrass quality than low mowing height especially during

Table 3. Mean Kentucky bluegrass quality for mowing height main effect of Kentucky bluegrass.

Mowing height[w]	Aug. 10	Aug. 20	Aug. 27	Sep. 4	Sep. 12	Sep. 22	Sep. 30	Oct. 6	Oct. 15	Oct. 22	Nov. 5
	Turfgrass quality										
40	6.0[x] b[y]	6.7b	6.9b	5.9b	5.6b	6.4b	6.7b	6.6b	5.4b	4.2b	5.6b
100	8.0a	9.0a	8.0a	8.0a	7.3a	7.1a	7.2a	7.4a	6.1a	5.2a	6.0a
	Daily air temperature (°C)										
Min. Temp.	21.8[z]	22.7	18.8	18.6	15.0	14.7	17.6	7.7	9.2	10.7	6.6
Avg. Temp.	25.1	24.3	23.3	23.9	18.0	21.4	20.6	15.8	15.7	16.8	11.6
Max. Temp.	29.4	28.5	29.0	30.2	22.4	30.4	24.4	25.6	24.3	23.9	19.4

[w]The unit of mowing height was millimeter (mm).
[x]Mean turfgrass quality was measured by visual evaluation using 1 to 9 scale (1=worst, 6=acceptable, and 9=best).
[y]Means in a column with the same upper case letters or no letters are not significantly different according to Fisher's LSD (P=0.05).
[z]Daily air temperature is not statistical data but reference data by weather-i.

Table 4. Mean Kentucky bluegrass quality for K rate main effect of Kentucky bluegrass.

K rate[w]	Aug. 10	Aug. 20	Aug. 27	Sep. 4	Sep. 12	Sep. 22	Sep. 30	Oct. 6	Oct. 15	Oct. 22	Nov. 5
	Turfgrass quality										
Low	7.0[x]	7.7	7.3	7.0	6.5	6.5	6.5b[y]	6.7b	5.7	4.5	5.8
Medium	7.0	7.8	7.5	6.8	6.3	7.0	7.2a	7.2a	5.8	4.8	5.8
High	7.0	8.0	7.5	7.0	6.5	6.8	7.2a	7.2a	5.8	4.8	5.7
	Daily air temperature (°C)										
Min. Temp.	21.8[z]	22.7	18.8	18.6	15.0	14.7	17.6	7.7	9.2	10.7	6.6
Avg. Temp.	25.1	24.3	23.3	23.9	18.0	21.4	20.6	15.8	15.7	16.8	11.6
Max. Temp.	29.4	28.5	29.0	30.2	22.4	30.4	24.4	25.6	24.3	23.9	19.4

[w]The low, medium and high K rate was 5, 10, and 20 g K_2O m^{-2}, respectively.
[x]Mean turfgrass quality was measured by visual evaluation using 1 to 9 scale (1=worst, 6=acceptable, and 9=best).
[y]Means in a column with the same upper case letters or no letters are not significantly different according to Fisher's LSD (P=0.05).
[z]Daily air temperature is not statistical data but reference data by weather-i.

summer months compared to spring or fall. It could be resulted from high photosynthesis and low respiration under large amount of sun light during summer which can be a source to produce carbohydrate. This is supported by Lambers (1985) reported that carbon fixation can be increased with high temperature. Unlike turfgrass color, turfgrass quality was influenced by mowing height regardless the temperature range. However, the 40 mm mowing height under the temperature below 24.3°C had lower turfgrass quality than an acceptable quality rating of six. If Kentucky bluegrass is needed to maintain greater turfgrass quality than the minimum acceptable quality under the temperature below 24.3°C, the 100 mm mowing height would be required. When the temperature is high during summer, the 100 mm mowing height would be needed for high quality Kentucky bluegrass which is turfgrass quality more than 7. Significant differences

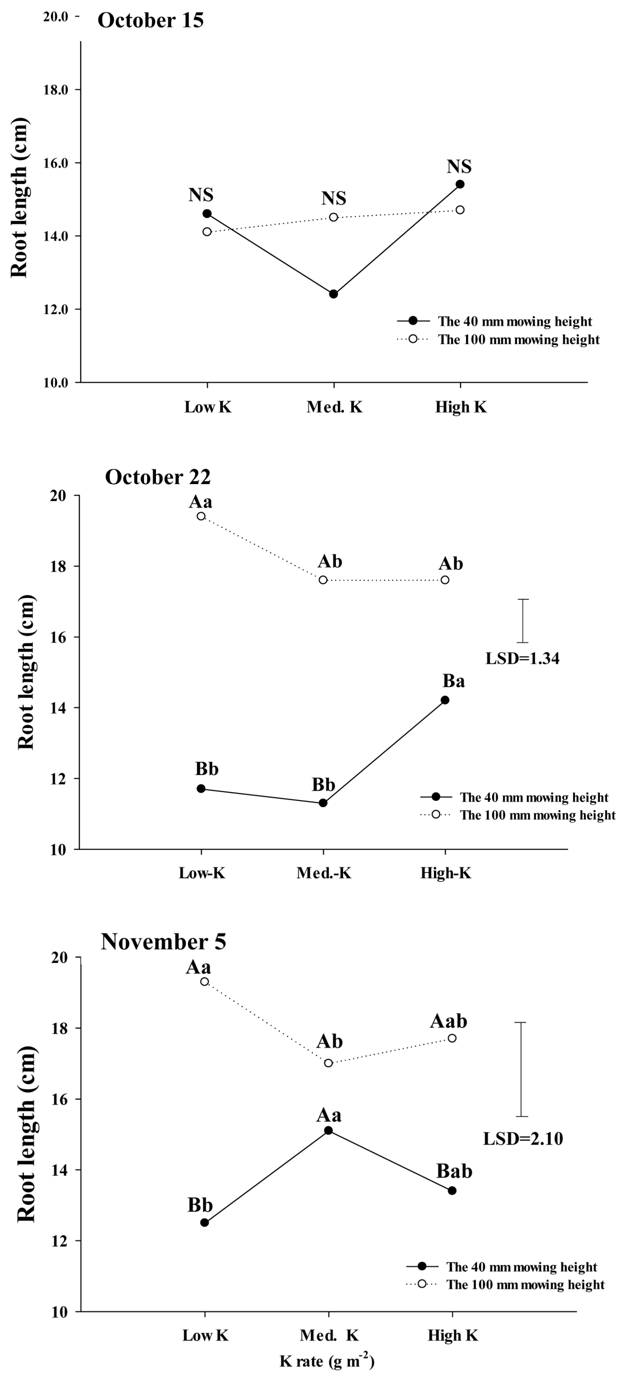

Fig. 1. Mowing height × K rate interaction for root growth of Kentucky bluegrass. The low, medium and high K rate was 5, 10, and 20 g K_2O m^{-2}, respectively. Means with the same upper case letters are not significant different between mowing heights according to Fisher's LSD test (P=0.05). Means with the same lower case letters are not significant among K rates according to Fisher's LSD test (P=0.05).

among K rates were found on turfgrass quality on September 30 and October 6 (Table 4). The medium and high K rates had the highest or equal to the highest turfgrass quality than the low K rate. This differences occurred when the maximum air temperature decreased from 30°C to 24.4°C. During the summer month when the maximum temperature was relatively high, turfgrass quality was not influenced by K rate. After the minimum temperature reached 7.7°C, no differences among K rates were found in turfgrass quality. Of all sampling dates, there were differences only for two of 11 sampling dates. Overall, no K rate effects were found on turfgrass quality.

Significant interactions were found between mowing height and K rate for root length on October 22 and November 5 (Fig. 1). When the maximum temperature was reached above 24°C which is the temperature range higher than the optimal temperature range for cool-season grasses, no interaction was found between mowing height and K rate for root length. With the 40 mm mowing height, the high K rate produced longer root length than the low and medium K rates. But the 40 mm mowing height with different K rates had inconsistent interaction between mowing height and K rate on root length. Unlike the measurement of root length on October 22, the medium K rate had the longest or equal to the longest root length on November 5. The low K rate had the longest root length among the k rates with the 100 mm mowing height. The low K had 9.3% longer root length than the medium and high K rate. It is supported by Carrow (1994) who evaluated N and K effects on creeping bentgrass. He reported that creeping bentgrass applied by the 14.7 g K m^{-2} had 35.3% longer root length than creeping bentgrass with the treatment of the 44.2 g K m^{-2}. When the maximum air temperature is optimal for cool-season grasses, the low K with the 100 mm mowing height had longer root length than the medium and high K rate.

When Kentucky bluegrass is stressed during summer and under high temperature, the mowing height of more than 100 mm is required to maintain high quality turfgrass. As known, K is an enzyme activator and K deficient turfgrass is susceptible to environmental stress such as high temperature. When the temperature was optimal for cool-season grasses, the K rate of more than 10 g K_2O m^{-2} had greater turfgrass quality. However, Kentucky bluegrass under high temperature of more than 28.5°C was not influenced by K rates. Overall, the high mowing height regardless K rates would be required if high turfgrass quality of Kentucky bluegrass is needed when the air temperature is higher than 28.5°C. When the air temperature is optimal, the high mowing height of more than 100 mm and the low K rate is needed for the growth of root length.

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