Effects of fall dormancy, cutting frequency, and K application rate on dry matter yield and nutritive value of alfalfa

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Key words: Alfalfa, Fall dormancy, Cutting frequency, K application rate, Dry matter yield

Abstract

[**Introduction**] This study was conducted to determine the effect of the cutting frequency and K application rate on the dry matter yield (DMY) and nutritive value of new alfalfa varieties in Korea. [**Material and Methods**] The sowing date and rate were September 21, 2019, and 20 kg/ha, respectively. The treatment was by the split-split plot design, and the main plot was the Fall dormancy (FD) of 3 (Rugged Rancher), 4 (SW4113), and 9 (SW9720), the sub-plot was excess 40 day (LCF), from 31 to 40 days (MCF), and under 30 day (HCF) times of cutting frequency (CF), and the sub-sub plot was 150 (K 150), 300 (K 300), and 450 (K 450) kg/ha of K application rate. The first harvest reached 10% of the flowering, and after the first harvest, it was conducted according to the cutting frequency treatment. The survey contents were investigated as DMY, Crude protein (CP), Neutral detergent fiber (NDF), Acid detergent fiber (ADF), and K content. [**Results and Discussion**] K 450 of DMY was significantly higher than K 150 ($p<0.05$). The CF was not significant at each level ($p>0.05$). FD 3 and FD 4 of DMY were significantly higher than FD 9 ($p<0.05$). The CP, NDF, and ADF according to FD and CF were significantly different at each treatment ($p<0.05$). The CP and ADF according to the K treatment were significantly higher at K 150 than K 300 and K 450 ($p<0.05$). In addition, the NDF according to the K treatment was significantly higher in K 150 and K 450 than K 300 ($p<0.05$). The K content of alfalfa significantly differed according to the K treatment ($p<0.05$). Therefore, it is judged that a high DMY can be expected when the K application rate, cutting frequency, and FD is 450 kg/ha, HCF, and 4, respectively.

Introduction

Alfalfa cultivation research has not been conducted in the past 20 years in Korea. So if a new variety of alfalfa is applied, a high Dry Matter Yield (DMY) can be expected. Fall Dormancy (FD) is one of the important considerations in the selection of alfalfa varieties (Dan, *et al.*, 2011; Ventroni *et al.*, 2010). FD was selected depending on the cultivation environment such as temperature, and it effected cultivation techniques. In particular, FD is closely related to Cutting frequency(CF) and the amount of potassium (K) fertilizer. The alfalfa DMY, quality, and persistence depend on the number of cutting (Dan *et al.*, 2011; Ventroni *et al.*, 2010). The appropriate CF of alfalfa in Korea is presented 3 times (RDA, 2019). This standard is based on past varieties, and the CF may change depending on the new variety considering FD. The K application rate is presented as 200 to 300 kg/ha without considering the alfalfa DMY (Park et al., 2005). If DMY increases due to the cultivation of new varieties, it is recommended to adjust the K application rate used according to the DMY (Mayer *et al.*, 2007). This study was conducted to confirm the effect of the cutting frequency and K application rate on the dry matter yield of new alfalfa varieties considering fall dormancy.

Methods and Study Site

The experiments were conducted at experimental field of Kangwon National University Farm and livestock Barn in Chuncheon, Republic of Korea (37°56'17.00"N , 127°47'7.62"E). The sowing date and rate were September 21, 2019, and 20 kg/ha, respectively. The experiment was fertilized at 300 kg/ha of Phosphate (P) and Potassium (K) followed treatment. P and K were applied as top dressing at 1st and 5th harvests and at each harvest, respectively.

The treatment was by the split-split plot design with 3 times replication. The main plot was the Fall dormancy rate (FDR) of FD 3 (Rugged Rancher), FD 4 (SW4113), and FD 9 (SW9720), the sub-plot was excess 40 day (LCF), from 31 to 40 days (MCF), and under 30 day (HCF) times of CF, and the sub-sub plot was 150 (K 150), 300 (K 300), and 450 (K 450) kg/ha of K application rate. The first harvest reached 10% of the flowering, and after the first harvest, it was conducted according to the CF treatment. The plot size was 2m X 4m (8m^2). Harvest date was presented in Table 1.

The survey contents were investigated as DMY, Plant height, Coverage, Alfalfa ratio Crude protein (CP), Neutral detergent fiber (NDF), Acid detergent fiber (ADF), Relative feed value (RFV), CP yield (CPY), and K and Magnesium (Mg) of alfalfa content. The quality of alfalfa was evaluated by relative feed value (RFV) and equation as followed (James, 2002); $\mathrm{RFV} = (\mathrm{DDM}\ (\%) \times \mathrm{DMI}\ (\%\ \mathrm{of\ Body\ weight}))/1.29$. Where, DDM = Digestible Dry Matter (%), $[\mathrm{DDM} = 88.9 - (0.779 \times \mathrm{ADF}\ (\%)]$, DMI = Dry Matter Intake (% of DM) $[\mathrm{DMI} = 120/ADF\ (\%)]$.

Among the meteorological data, the daily mean temperature was measured on hourly interval by putting a data logger (DT-172, CEM) at the experimental site, and was calculated according to the standards of the Korea Meteorological Administration (KMA). Precipitation was collected from the weather data service-Open MET data portal on KMA (data.kma.go.kr), and the meteorological information used were Bukchuncheon weather station, the closest meteorological station to the experimental site. The daily mean temperature and precipitation during the normal year (30-years) and experiment period of Bukchuncheon weather station was presented in Fig. 1. Annual precipitation was 1,341.5 mm in the normal year (30 years) and 1,090.2 mm in the experimental year, respectively.

Analysis of variance (ANOVA) analyzed SAS 9.4 (PROC GLM) method procedure (SAS Institute Inc., 2013). Means differences between treatments were reported using the Least Significant Difference (LSD) test at p = 0.05 significance level.

Table 1. Harvest date of alfalfa according to cutting frequencies

	LCF[1)]	MCF[2)]	HCF[3)]
1st	26. May	26. May	26. May
2nd	13. Jul.	29. Jun.	23. Jun.
3rd	26. Aug.	04. Aug.	20. Jul.
4th	12. Oct.	09. Sep.	18. Aug.
5th		12. Oct.	13. Sep.
6th			12. Oct.

[1)] Low cutting frequency, [2)] Medium cutting frequency, [3)] High cutting frequency.

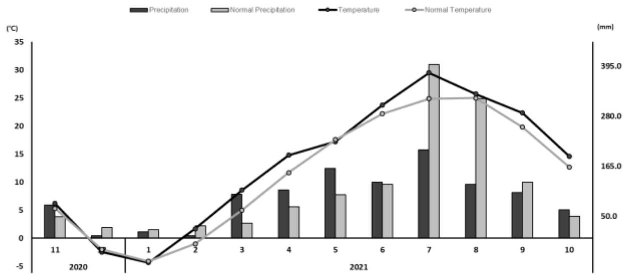

Fig. 1. Monthly Normal(30-year) and experimental periods of temperature average and accumulated precipitation.

Results and Discussion

Dry matter yield

DMY according to FDR was 20,475.0, 21,956.1, and 15,601.9 kg/ha for FD 3, 4, and 9, respectively, and FD 3 and FD 4 were significantly higher than FD 9 ($p<0.05$, Table 2). The reason the DMY of FD 3 and FD 4 was higher than that of FD 9 was judged to be that the plant height was low ($p<0.05$), but the coverage and botanical composition of alfalfa were high($p<0.05$). Although there was no difference in alfalfa DMY according to the CF ($p>0.05$, Table 2), it tended to decrease as the CF increased. Plant height, coverage, and botanical composition of alfalfa according to the CF all decreased as the level of the CF increased ($p<0.05$). LCF was lodging in all harvest, and the plant height reached 98.5 cm. Considering that Haki *et al.*(2012) does not recommend reaching alfalfa over 80cm, LCF is not considered suitable. DMY according to K treatment, K 150, K 300, and K 450 were 18,610.1, 19,220.1, and 20,202.9 kg/ha, respectively, and K 300 and K 450 were higher than K 150 ($p<0.05$, Table 2).

Chemical composition

CP content according to FDR was 21.7, 22.2, and 20.3% of FD 3, FD 4, and FD 9, respectively, and there was a significant difference at each level ($p<0.05$, Table 3). It was consistent with the result that the leaf and stem ratio varied depending on the FDR, and as the FDR increased, the stem ratio increased and CP content decreased (Avci *et al.*, 2018). Depending on the CF, LCF, MCF, and HCF were 19.2, 22.2, and 22.9%, respectively, showing significant differences at each level ($p<0.05$). As the CF increased, the CP content tended to increase, which was the same results presented by Min (2016), Xu *et al.* (2021), and Atis (2019). According to K treatment, K 150, K 300, and K 450 were 21.5, 21.4, and 21.3%, respectively, and K 150 was significantly higher than K 300 and K 450 ($p<0.05$).The CP content decreased with an increase in the K treatment, the same as the results of Jungers *et al.* (2019) and Lissbrandt *et al.* (2009).

NDF and ADF content according to FDR were significantly different at each level ($p<0.05$, Table 3), and FD 4 was the lowest and FD 9 was the highest. The NDF and ADF content were high at FD 9. This is judged to be because the leaf and stem ratio was different depending on the FD and Non-dormant varieties have a high stem ratio due to fast re-growth (Avic *et al.*, 2018). The NDF and ADF content according to the CF were significantly different in each level (p<0.05) and decreased as the CF increased. This is considered to be because as the CF increases, alfalfa is harvested at an early growth stage such as early bud, so the NDF and ADF content was higher due to the growth stage of LCF later than MCF and HCF. The NDF content according to the K treatment was significantly higher for K 150 and K 450 than K 300 (p<0.05). ADF content was significantly K 150 higher than K 300 and K 450 (p<0.05). This is Lissbrant *et al.* (2009) reported that the contents of NDF and ADF increased as the amount of K treatment increased, which was consistent with the results of this study.

RFV was 117.9, 121.7, and 114.0 of FD 3, FD 4, and FD 9, respectively, with significant differences at each level (p<0.05, Table 3), and FD 4 was the highest. LCF, MCF and HCF increased as the CF increased (p<0.05). The RFV decreased as the K treatment increased (p<0.05), and it was judged that increases in the K treatment contributed NDF and ADF content increased.

Crude protein yield

CPY of FD 3, FD 4, and FD 9 were 4,056.4, 4,493.5 and 2,998.2 kg/ha, respectively, which differed at each treatment, and FD 4 was the highest. CPY according to the CF was no difference (p>0.05). CPY according to the CF was the highest in MCF, although there was no significant difference according to the treatment(p>0.05). CPY of K 150, K 300, and K 450 were 3,716.4, 3,818.7 and 4,013.0 kg/ha, respectively, and K 300 and K 450 were higher than K 150 (p<0.05).

Tissue analysis

The K content of alfalfa depending on the K treatment was 2.15, 2.43, and 2.55% of K 150, K 300, and K 450, respectively, and was significantly high at each level (p<0.05, Fig. 2). Lioveras et al. (2012) found that the K content of alfalfa ranged from 0.77 to 2.46% when the K treatment was 0 to 400 kg/ha per year, which was similar to the result. On the other hand, it was consistent with the result that the alfalfa K content increased according to the increase in K treatment. The Mg content of alfalfa depending on the K treatment, and K 150 and K 300 were significantly higher than K 450 (p<0.05, Fig. 2). The Mg content of alfalfa decreased according to the K treatment, which coincided with the result that the amount absorbed by alfalfa decreased (Lanyon and Griffith, 1988) because the absorption of Mg in alfalfa competes with K.

Conclusions

Considering the DMY, CP, CPY, and RFV, the optimal fall dormancy rate is 4 and the K application is 450 kg/ha. On the other hand, there was no difference between DMY and CPY by the cutting frequency, but considering that it became a lodging, LCF was inappropriate, NDF and ADF were low, and RFV high HCF was appropriate.

Table 2. Dry metter yield, plant height, coverage, and botanical composition of alfalfa subjected to fall dormancy rate, cutting frequencies, and K application rate

	Dry matter yield	Plant height	Coverage	Botanical composition
	----- kg/ha -----	----- cm -----	----------------------------- %	-----------------------------
FDR[1)] (A)				
FD[2)] 3	20,475.0 ± 2,432.1 a	80.6 ± 14.0 b	87.9 ± 3.5 a	91.4 ± 5.9 ab
FD 4	21,956.1 ± 2,715.2 a	82.0 ± 11.8 b	88.8 ± 2.9 a	93.6 ± 4.7 a
FD 9	15,601.9 ± 2,183.0 b	85.5 ± 11.9 a	84.8 ± 6.0 b	88.8 ± 8.7 b
Cutting frequencies (B)				
LCF[3)]	20,050.3 ± 3,880.0	98.5 ± 5.4 a	90.4 ± 1.8 a	96.7 ± 2.3 a
MCF[4)]	19,302.8 ± 3,276.9	79.1 ± 4.7 b	87.4 ± 2.4 b	92.5 ± 4.1 b
HCF[5)]	18,680.0 ± 3,773.4	70.5 ± 3.3 c	83.7 ± 5.7 c	84.6 ± 6.7 c
K application rates (C)				
K 150	18,610.1 ± 2,875.0 b	82.0 ± 12.3	87.2 ± 5.0	90.8 ± 6.8
K 300	19,220.1 ± 3,805.4 ab	82.8 ± 12.5	86.7 ± 4.6	90.7 ± 7.2
K 450	20,202.9 ± 4,113.5 a	83.3 ± 13.5	87.6 ± 4.3	92.3 ± 6.7
Ave.	19,344.4 ± 3,650.7	82.7 ± 12.6	87.2 ± 4.6	91.3 ± 6.8
interaction				
A × B	0.65	**	**	0.08
A × C	0.33	0.19	0.46	0.78
B × C	0.67	0.14	0.64	0.85
A × B × C	0.60	0.91	0.67	0.07

[1)] Fall dormancy rate, [2)] Fall dormancy, [3)] Low cutting frequency, [4)] Medium cutting frequency, [5)] High cutting frequency. [abc] Different superscripts indicates that each treatment differ within the same column (p<0.05), ** Significant difference at p<0.01.

Table 3. Chemical composition and relative feed value of alfalfa subjected to fall dormancy rate, cutting frequencies, and K application rate

	CP[1)]	NDF[2)]	ADF[3)]	RFV[4)]
	----- % of DM -----			
FDR[5)] (A)				
FD[6)] 3	21.7 ± 4.1 b	48.8 ± 5.7 b	36.4 ± 5.2 b	117.9 ± 22.1 b
FD 4	22.2 ± 4.0 a	48.0 ± 5.7 c	35.3 ± 5.5 c	121.7 ± 22.2 a
FD 9	20.3 ± 3.5 c	49.9 ± 4.6 a	36.7 ± 5.0 a	114.0 ± 17.2 c
Cutting frequencies (B)				
LCF[7)]	19.2 ± 2.3 c	52.6 ± 5.6 a	39.6 ± 5.7 a	104.7 ± 20.0 c
MCF[8)]	22.2 ± 3.8 b	47.9 ± 4.7 b	36.1 ± 3.8 b	119.8 ± 17.6 b
HCF[9)]	22.9 ± 4.3 a	46.2 ± 4.2 c	32.7 ± 4.1 c	129.1 ± 18.0 a
K application rates (C)				
K 150	21.5 ± 3.9 a	49.2 ± 5.1 a	36.5 ± 5.1 a	116.4 ± 19.4 c
K 300	21.4 ± 4.0 b	48.4 ± 6.0 b	35.9 ± 5.7 b	120.0 ± 23.0 a
K 450	21.3 ± 4.1 b	49.1 ± 5.1 a	36.0 ± 5.1 b	117.3 ± 19.8 b
Ave.	21.0 ± 4.0	48.0 ± 5.4	35.5 ± 5.3	115.7 ± 20.8
interaction				
A × B	**	0.06	**	**
A × C	**	**	**	**
B × C	**	**	**	**
A × B × C	**	**	**	**

[1)] Crude Protein, [2)]Neutral Detergent Fiber, [3)]Acid Detergent Fiber, [4)]Relative Feed Value, [5)] Fall dormancy rate, [6)] Fall dormancy, [7)] Low cutting frequency, [8)] Medium cutting frequency, [9)] High cutting frequency. [abc] Different superscripts indicates that each treatment differ within the same column (p<0.05). ** Significant difference at p<0.01.

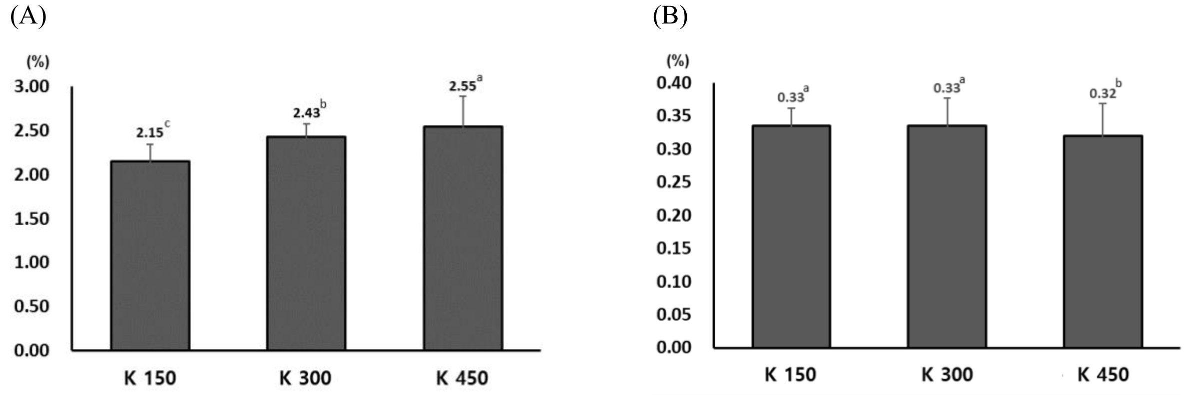

Fig. 2. Alfalfa tissue analysis test of potassium (A) and magnesium (B) by K application rate.

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