Cutting Interval Effects on Dry Matter Yield and Nutritive Value of Alfalfa under Rainfed Condition in South Korea

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10.18805/LRF-888

ABSTRACT

Background: This study aimed to evaluate the effects of cutting interval on alfalfa (*Medicago sativa* L.) production and nutritive value in the central region of South Korea under rainfed conditions.

Methods: Alfalfa was sown using a drill seeding method at a rate of 20 kg ha^{-1} on March 18, 2020. The experiment followed a randomized complete block design with three cutting interval treatments (28-, 36- and 48-day intervals). A regression model was developed to analyze both accumulated dry matter yield (DMY) and average crude protein (CP), as well as average relative feed value (RFV).

Result: Accumulated DMY at 48- and 36-day intervals appeared higher than the 28-day interval (P<0.05). In terms of nutritive value, the 48-day interval resulted in significantly lower CP, compared to the other cutting intervals (P<0.05). RFV of 28- and 36-day intervals were significantly higher than the 48-day interval (P<0.05). The crossover of the linear regression model between accumulated DMY with average CP and average RFV indicated a cutting interval of 32-day, respectively. Taken together, the field study and regression results support a recommended cutting interval of around 36 days, which is about two weeks shorter than the conventional cutting interval under rainfed conditions in the central region of South Korea.

Key words: Alfalfa, Cutting interval, Dry matter yield, Nutritive value, Rainfed conditions.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most important forage crops, particularly for high-performing ruminants and calves, due to its high crude protein (CP) content (Putnam and Orloff, 2014). For this reason, the demand for alfalfa among livestock farmers in South Korea is on the rise. However, alfalfa in the South Korean market is entirely dependent on imports with a sustained growth rate of 2.3% per year (Kim *et al.*, 2023). In addition, in recent years, the United States has reduced the export volume and raised prices of alfalfa due to production declines attributed to climate change (Chang *et al.*, 2024; RDA, 2022). These market conditions underscore the need to expand domestic production.

Although alfalfa cultivation techniques were developed in South Korea two decades ago (Kim *et al.*, 2023), recent climate-driven declines in yield now require updated management practices (Lee *et al.*, 2021). As forage production in South Korea is predominantly rainfed, climate-driven shifts in precipitation directly affect alfalfa production (Glenn *et al.*, 2013; Suat *et al.*, 2007; Undersander *et al.*, 2011a; Undersander *et al.*, 2011b). From the 1970s to the 2000s in South Korea, the precipitation regime from spring to autumn was relatively regular, progressing from a dry spring to the summer rainy season, followed by a hot and humid conditions and a dry autumn (Kim *et al.*, 2011). Since about 2000, greater variability in precipitation timing, intensity and amount has emerged, suggesting a need to reschedule cutting interval under rainfed conditions. (Chang and Kwon, 2007). Because alfalfa in this rainfed is strongly influenced by seasonal precipitation, the cutting interval and cutting frequency are likely to differ from those under conventional management.

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How to cite this article: Kim, J.Y., Min, D., Peng, J., Sung, K.I., Kim, M., Baral, R. and Kim, B.W. (2026). Cutting Interval Effects on Dry Matter Yield and Nutritive Value of Alfalfa under Rainfed Condition in South Korea. *Legume Research*. **49(5):** 844-849. doi: 10.18805/LRF-888.

Submitted: 12-07-2025 **Accepted:** 18-12-2025 **Online:** 06-01-2026

Cutting interval is a key factor in balancing the agronomic trade-off among alfalfa yield, forage quality and stand persistence (Putnam, 2021). Shorter cutting intervals improve nutritive value by cutting at earlier maturity, whereas longer cutting intervals favor yield accumulation and crownroot reserve recovery, thereby supporting stand longevity (Xu *et al.*, 2021; Undersander *et al.*, 2011a). The cutting frequency of alfalfa in South Korea was previously reported as three times (RDA, 2022) or four times (Kim *et al.*, 2023), with cutting intervals exceeding 50 days. Accordingly, we evaluated cutting management and sought to define a practical cutting interval window under rainfed conditions in South Korea.

This study aimed to evaluate the effects of different cutting intervals on the alfalfa yield and nutritive value under rainfed conditions in South Korea.

MATERIALS AND METHODS

Study site and preparing the field experimental stand

This study was conducted at the Forage Research Field of Kangwon National University, located in the central region of South Korea. The soil was sandy loam with a pH of 4.8, organic matter of 15.6 g kg^{-1}, available P_2O_5 of 53.3 mg kg^{-1}, exchangeable calcium (Ca), potassium (K) and magnesium (Mg) of 4.4, 0.1 and 0.8 cmolc kg^{-1} and total nitrogen (N) of 0.08%. Because the pH, available P_2O_5 and exchangeable K contents were below the recommended levels (RDA, 2019), we amended the soil with fertilizers to correct fertility. Lime was applied at 3,000 kg/ha before sowing. The N-phosphate (P)-K-Boron (B) fertilizers were applied at 100-300-300-20 kg ha^{-1}, respectively, in the establishment year (2020). N and B were not applied during production years (2021 and 2022). The alfalfa cultivar Vernal was sown by drilling at 20 cm row spacing on March 18, 2020 and a seeding rate of 20 kg pure live seed ha^{-1}.

Treatments

Three cutting intervals (28-, 36- and 48-day) with three replications each were applied in a randomized complete block design, with each plot a size of 2 m × 4 m. The first harvest was conducted at 10% flowering, with subsequent cuttings based on the assigned treatments. Due to the severe drought in the establishment year, the first harvest was delayed by two months and taken on July 16, followed by the cutting intervals of 28-, 36- and 48-days. Also, in the first and second production years, the first harvest was conducted on May 19 and 20, respectively and the last harvest was conducted on October 8 and 6, respectively, for each treatment. After the first cut, each plot was harvested according to cutting interval treatments in both production years.

Measurements, data collection and data analysis

Plant height was measured on five randomly selected plants per plot. Coverage (0 indicating bare ground and 100% indicating full cover) was visually estimated as the proportion of ground covered by alfalfa within each plot. Alfalfa samples were collected by cutting height at a 7 to 10 cm stubble and then were dried in forced-air ovens at 65°C for 72 h to determine dry matter yield (DMY; kg ha^{-1}). Dried alfalfa samples were ground in a 1mm mill (Fritsch, Germany) for laboratory analysis. CP content was analyzed using the Dumas method (Rapid Nexced, Elementar, Germany) according to AOAC (2006). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were analyzed using an ANKOM fiber analyzer (ANKOM 2200, ANKOM Tech., USA) following Goering and Van Soest (1970). Relative feed value (RFV) and total digestible nutrients (TDN) were calculated following James (2002).

Weather data, including monthly precipitation and 30-year average temperature and precipitation, was obtained by the Bukchuncheon Automated Synoptic Observing System (ASOS) in Chuncheon, Gangwon-do during the study. Daily mean temperature at the experimental site was recorded using a data logger (DT-172, CEM, China).

Data was analyzed using SPSS 24 (IBM, 2019). Treatment means differences of measured data were compared using the least significant difference (LSD) test at a 95% significance level. The cutting interval was determined by linear regression as the crossover among curves for accumulated DMY with average CP and average RFV using curve estimation based on Grev *et al.* (2017) and Putnam (2021).

RESULTS AND DISCUSSION

Climate during experiment periods

The monthly mean temperature and monthly precipitation are shown in Fig 1a and Fig 1b, respectively. The monthly mean temperature during the experimental period was higher than the 30-year monthly mean in all years, with particularly large increases in March. Annual precipitation was 1,470, 1,065 and 1,516 mm in the establishment, first and second production years, respectively, compared with the 30-year mean of 1,342 mm. In the establishment year, August precipitation was 821 mm, approximately 2.6 times the 30-year mean and the rainy season lasted 54 days. These excessive rainfall patterns negatively affected alfalfa growth (Fig 1b). In contrast, the first production year of precipitation and the rainy season showed lower than the 30-year mean (KMA, 2022). The second production year experienced a severe spring drought, whereas the summer rainy season was 33 days, similar to the 30-year mean (KMA, 2023).

Alfalfa yield and nutritive value in the establishment year

During the establishment year, DMY, plant height and coverage at the 48-day interval were significantly higher than at the 28-day interval ($P<0.05$, Table 1). For nutritive value, CP content was significantly higher at the 28- and 36-day intervals than at 48-day interval ($P<0.05$, Table 1), whereas fiber contents, including ADF and NDF, were significantly higher at 48-day interval than at other treatments ($P<0.05$, Table 1). These affected TDN and RFV were significantly higher at the 36-day interval than at the other intervals ($P<0.05$, Table 1). Overall, nutritive value declined with longer intervals. These results are consistent with previous findings (Min, 2016; Putnam, 2021; Xu *et al.*, 2021; Xu and Min, 2022) showing that shorter cutting intervals are associated with younger alfalfa maturity (Karayilanli and Ayhan, 2016). However, in this study the fiber content at 28-day interval was higher than at 36-day interval, likely due to uneven rainfall distribution. High summer precipitation and prolonged rainfall can saturate soil, hinder alfalfa root development (Zhang *et al.*, 2019) and trigger nutrient translocation from leaves to roots, ultimately reducing nutritive value (Buxton, 1996). Low autumn precipitation can lead to drought-induced leaf loss in alfalfa, increasing fiber content (Buxton, 1996). Additionally, alfalfa requires recovery time after waterlogging (Barta and Sulc, 2002) and the 28-day interval may be insufficient. These findings suggest that the fiber content may be higher at a 28-day interval than at a 36-day interval. Taken together, the 36-day interval provided the best balance of yield and nutritive value, especially CP and RFV, in the establishment year.

Cutting interval based on field study and linear regression model in production years

DMY increased significantly as the cutting interval lengthened (P<0.05, Table 2). In both production years, the 48-day interval produced the highest DMY, although yield fluctuation differed between years (Fig 2a and 2b). Longer cutting intervals also resulted in significantly higher plant height and coverage (P<0.05), which were positively associated with DMY (Griggs and Stringer, 1988). This was also observed in the findings of Atis *et al.* (2019), Min (2016) and Probst and Smith (2011), who reported that DMY increased with longer cutting intervals. Accumulated DMY, which was the total DMY in both production years, significantly increased with longer cutting intervals, reaching 21,771, 26,139 and 29,390 kg ha^{-1} at 28-, 36- and 48-day intervals, respectively (P<0.05), with higher yields at 36- and 48-day intervals than at 28-day interval. DMY differed by roughly a factor of two between the first (Fig 2a) and second (Fig 2b) production years. Because the experiment relied on rainfed conditions, both the amount and seasonal distribution of precipitation were key determinants of alfalfa growth, regrowth and yield (Baral *et al.*, 2022; Shewmaker *et al.*, 2011). In the first production year, relatively even distributed rainfall from March to October resulted in a 212% higher DMY compared to the second production year. By contrast, a severe May drought in the second production year restricted water for the first harvest, which typically accounts for over 50% of annual yield, thereby

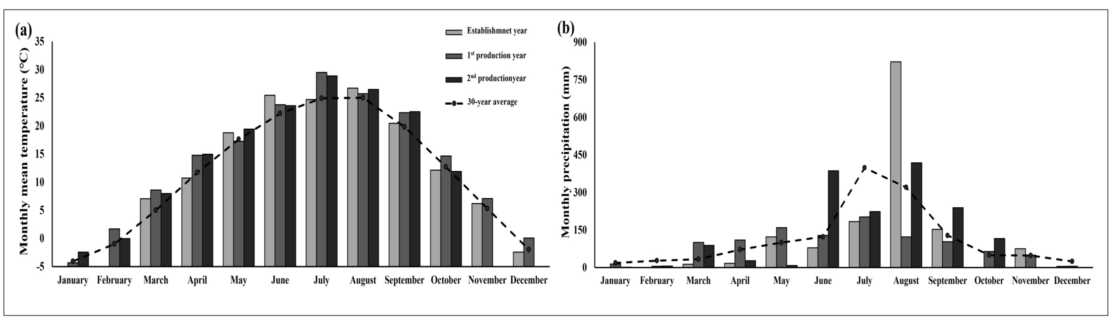

Fig 1: Monthly mean temperature (a) and precipitation (b) of experiment place for 30-year average and experiment years.

Table 1: Dry matter yield, growth characteristics and nutritive value of alfalfa by cutting intervals for establishment year.

	DMY	Plant height	Coverage	CP	ADF	NDF	TDN	RFV
	-- kg ha^{-1} --	-- cm --	---%--------------------------					
28-days	4,358.2±631.1 b	33.5±2.0 b	72.2±5.3 c	24.4±1.0 a	29.3±0.9 b	43.5±1.4 b	60.4±0.7 b	145.2±7.1 b
36-days	5,364.0±1,045.9 ab	38.7±4.2 a	79.3±3.3 b	24.6±0.5 a	27.5±0.8 c	42.8±0.3 b	61.7±0.6 a	151.8±2.3 a
48-days	5,398.2±1,373.8 a	41.9±6.0 a	85.6±6.8 a	21.5±0.2 b	32.9±1.6 a	46.9±1.4 a	57.7±1.2 c	126.8±5.1 c

Note: DMY: Dry matter yield; CP: Crude protein; ADF: Acid detergent fiber; NDF: Neutral detergent fiber; TDN: Total digestible nutrients; RFV: Relative feed value. *abc: Means within the same column with different superscripts differ (P<0.05).

Table 2: Dry matter yield, growth characteristics and nutritive value of alfalfa by cutting intervals for production years.

	DMY	Plant height	Coverage	CP	ADF	NDF	TDN	RFV
	---kg ha^{-1}---	--- cm ---	--------------------------------------%----------------------------------					
28-days	10,885.3±5,132.7b	53.1±12.2 b	75.9±6.7 b	22.1±1.9 a	30.9±0.7 b	45.8±1.5 b	59.1±0.5 a	133.8±3.5 a
36-days	13,069.6±5,786.8ab	62.5±15.6 ab	76.5±14.4 b	21.8±2.0 a	32.5±3.2 b	45.9±1.0 b	58.0±2.4 a	130.3±8.2 a
48-days	14,695.2±4,213.2a	79.6±14.9 a	86.9±4.9 a	19.0±1.2 b	37.1±1.2 a	50.5±1.2 a	54.5±0.9 b	113.6±4.2 b

Note: DMY: Dry matter yield; CP: Crude protein; ADF: Acid detergent fiber; NDF: Neutral detergent fiber; TDN: Total digestible nutrients; RFV: Relative feed value. *abc: Means within the same column with different superscripts differ (P<0.05).

reducing overall yields (Wang *et al*., 2023; Glenn *et al*., 2013; Suat *et al*., 2007; Vaughn *et al*., 1990). In addition, heavy summer rainfall negatively affected the third and fourth harvests in the second production year. These seasonal shifts, characterized by dry springs and wet summers, negatively impacted alfalfa growth and yield.

As for nutritive value, CP content at 28- and 36-day intervals was significantly higher than at 48-day interval ($P<0.05$, Table 2), whereas ADF and NDF contents were significantly higher at the 48-day interval than at the shorter treatments ($P<0.05$, Table 2). Thus, harvesting at a 48-day interval reduced nutritive value. These findings were consistent with Xu *et al.* (2021), Atis *et al.* (2019), Min (2016) and Daniel *et al.* (2007), which report that the nutritive value declines as the cutting interval increases. Consistently, both TDN and RFV were significantly lower at the 48-day interval compared to the shorter cutting intervals ($P<0.05$, Table 2). The cutting interval of 48-day for the production years was close to 50 days, resulting in decreased forage quality due to the loss of leaves and stems in the lower part of alfalfa (Djaman *et al*., 2020; Min, 2016). This was similar to the late maturity of alfalfa, where the delay in cutting interval has been shown to decrease digestibility through increasing the rate of lignification of the stem cell wall,

Table 3: The effects of accumulated dry matter yield, average crude protein and average relative feed value on cutting interval by linear regression analysis.

Factors	Intercept	x	*P*-value	R^2
Accumulated DMY	11,867.5	372.3	< 0.001	0.589
Average CP	26.974	-0.161	< 0.001	0.866
Average RFV	164.839	-1.043	< 0.001	0.884

Note: DMY: Dry matter yield; CP: Crude protein; RFV: Relative feed value.

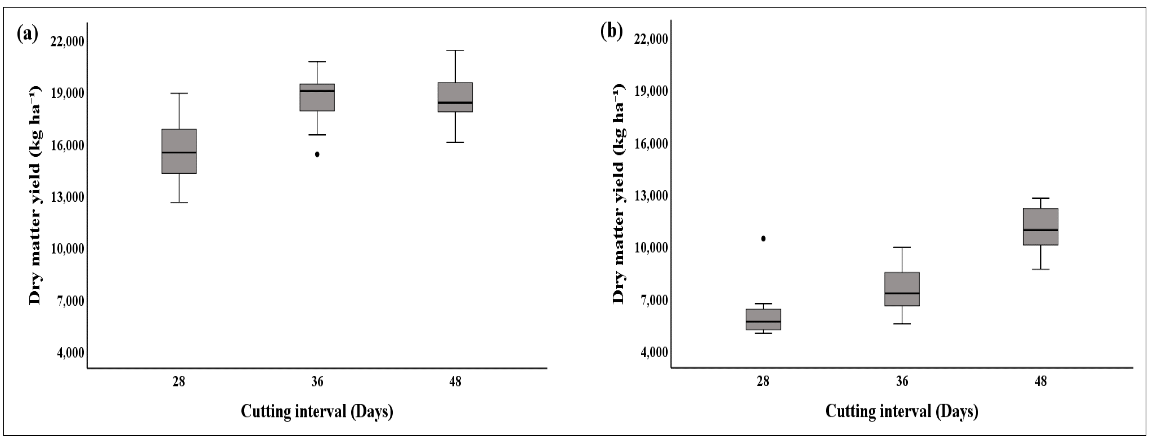

Fig 2: The distribution of dry matter yield by cutting intervals for (a) first and (b) second production years.

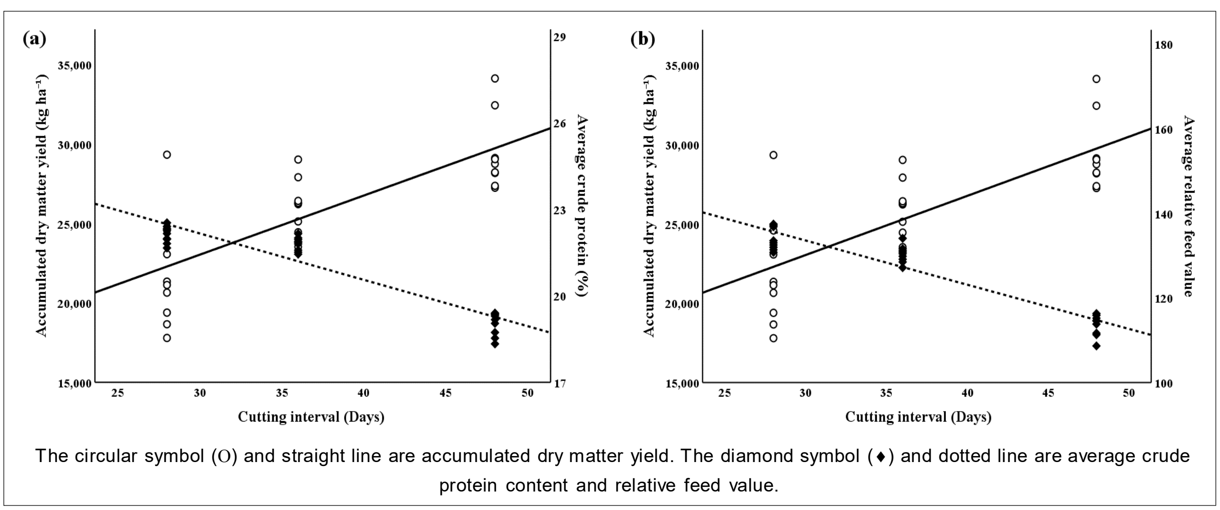

Fig 3: The relationship between accumulated dry matter yield and average crude protein content (a) and relative feed value (b) of alfalfa by cutting intervals during production years.

even as yields remain high (Marković *et al*., 2022; Grev *et al*., 2017; Karayilanli and Ayhan, 2016).

These results highlight the trade-off between DMY and nutritive values across cutting intervals. Both 48- and 36-day cutting intervals produced high accumulated DMY, whereas the 28-day cutting interval resulted in high nutritive value. Notably, the 36-day cutting interval provided a balance of yield and nutritive value, particularly CP and RFV under the rainfed conditions of this study.

In the linear regression, R^2 values for cutting interval with accumulated DMY as well as average CP and RFV were 0.589, 0.866 and 0.884, respectively, all statistically significant ($P<0.05$, Table 3). The cutting interval was determined as a crossover between the accumulated DMY with the average CP and RFV, occurring around 31.8 days (Fig 3a) and 31.4 days (Fig 3b), respectively. Thus, the regression results indicated near 32 days, between the 28- and 36-day cutting interval treatments. While the regression analysis points to a cutting interval window between 28- and 36-day, integrating the field study result suggests that the 36-day cutting interval treatment is preferable, as it increased alfalfa yield with no significant decrease in nutritive value. Also, Probst and Smith (2011) proposed 35 days as an optimum cutting interval in Kentucky, under rainfed conditions similar to those in our study, balancing forage yield and stand persistence. Considering both our field study results and the regression-based cutting interval, the 36-day cutting interval appears appropriate for rainfed conditions in South Korea. Overall, these results indicate that the cutting interval can be shorter than the conventional cutting interval, with a cutting interval of approximately 36 days. This also suggests adopting shorter cutting intervals than conventional practices in South Korea under the rainfed conditions, potentially allowing an increase in the cutting frequency.

CONCLUSION

This study aimed to identify the cutting interval for cultivating the high yield and nutritive value of alfalfa under rainfed conditions in the central region of South Korea. The cutting interval for alfalfa was 36 days in field study and approximately 32 days in regression analysis, determined under rainfed conditions and with both yield and nutritive value, particularly CP and RFV, considered. These intervals are about two weeks shorter than the conventional 50-day cutting interval. Given the recent seasonal variability in precipitation in South Korea, our findings indicate that shortening the cutting interval is advisable for producing high quality alfalfa compared with periods of a regular precipitation pattern.

ACKNOWLEDGEMENT

The present study was supported through the “Damage assessment in forages and development of cultivation technology for their damage reduction according to extreme weather (RDA-PJ01499604)” through Rural Development Administration, Korea.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

This research did not involve any animal experiments.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsor-ship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscrip.

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