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# Effects of Cutting on Alfalfa Yield and Quality in Northeast China

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**Abstract:** To clear that the yield components and quality of alfalfa (*Medicago sativa* L.) affected by cutting frequency, an experiment was conducted in Northeast China including 3 cutting frequency (F30, 40 and 60) among 3 cultivars (Longmu, C1; Aohan, C2; Zhaodong, C3). Result from this study showed that between cultivars and cutting frequency, the latter had a greater effect on forage yield and yield components at F40. Cultivars had no effect on 2 years total forage yield and alfalfa quality. At the F40, alfalfa always had higher CP and NDF than F30 and F60 treatments. The interaction of Cultivars (C) and cutting Frequency (F) on alfalfa productivity (yield and yield components) and quality (CP and NDF) was not significant. This study provides evidence that: cutting intervals of 40 days (three cuttings) can be advocated for cultivars growing in Northeast China and at F40 utilization, Longmu alfalfa is a well-adapted alfalfa variety in the Songnen Plain due to higher yield and quality under three cuttings.

**Key words:** Alfalfa, cutting, field, quality, songnen, NDF

## INTRODUCTION

Alfalfa (*Medicago sativa* L.) is an important crop planted for over 2,000 years in China (Li *et al*., 2010) with a great contribution to the development of agriculture and animal husbandry (Han *et al*., 2005). In China, the Northeast is an ecotone system between agriculture and animal husbandry (Tang *et al*., 1996). The diet of animals in this area nearly exclusively relies on forage production characterized by a low-quality and a short period of production (Chen *et al*., 2010). So, insufficient feed supplies in the winter season seriously restrict the productivity of livestock (Long, 1995; Dong *et al*., 2003). Therefore, alfalfa had played an important role in eliminating the seasonal imbalance between livestock and forage yield in Northeast areas of China which is one of the most valuable crops due to its great yield potential, high nutritional value and a wide adaptation. In many countries, alfalfa is grown primarily for forage production to enhance livestock production.

To explore the best management practices of alfalfa, more attention must be paid to cutting frequency. In fact, cutting frequency, a critical factor influencing both productivity and persistence (Keoghan, 1982) is generally associated with the flowering time. This represents an extremely important variable being a trade-off among quantity, quality and duration of the meadow (Teixeira *et al*., 2008). Moreover, these parameters are strongly linked to climatic conditions, management techniques, regrowth capability of the varieties and nutritional requirements for the livestock. Researchers had found that harvest time can affect forage yield and quality (Ghanbari Bonjar and Lee, 2003). The aim to improve forage quality without reducing yields can be achieved by increasing the cutting frequency (Marten *et al*., 1988). However, it is not clear whether the higher forage yield and the better digestibility compensate.

Cutting is known to effect three yield components: plants/area, shoots/plant and mass/shoot (Volenec *et al*., 1987) but it remains unclear which of the components are most affected and if its effect is similar among cultivars. Teixeira *et al*. (2007b) observed that mass/shoot was reduced with frequent cutting. Davis and Peoples (2003) reported that plants/area was reduced when alfalfa plants were cut frequently. In contrast, Belanger *et al*. (1992) observed similar rates of plant mortality among alfalfa varieties subjected to different defoliation frequencies. Nelson *et al*. (1986) reported that the number of shoots per square meter (shoots/m$^2$) was reduced when alfalfa plants were cut frequently.

The purpose of the present study was to test the influence of cutting frequency on the productive and qualitative characteristics of three alfalfa cultivars. The objectives were to comprehend if cutting affect alfalfa

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productivity (yield and yield components) and quality (CP and NDF) and to determine if these varieties had higher yield and quality with increased cutting frequency.

## MATERIALS AND METHODS

**Region and site description:** The research station has an altitude of 160 m, 125°58'E and 46°32'N in the North-Western of Songnen Plain, China. The climate is classifed as a typical chillness semi-wetness monsoon environment. The total yearly sunshine duration is 2713 h and the frost-free period is 130 days. The annual mean air temperature is 5.3°C with a maximum temperature of 31.2°C in July and a minimum temperature of -25.2°C in January. Average annual accumulated heat units (above 10°C) are 2,760°C. The average annual precipitation is 469.7 mm of which about 75% falls between June and August and the evaporation is about 950 mm. The soil is dark loam (mostly Chernozem, FAO Taxonomy) with high melanic humus. Maize (*Zea mays* L.) was the earlier crop on this field. The experiment was seeded on 1 May, 2008 and crops grew for 2 years until 2010. The climate variables (rainfall, maximum and minimum temperatures) were recorded daily and are reported as average monthly data in Fig. 1.

**Experimental design:** The treatments were a factorial combination of three alfalfa cultivars (same fall dormancy): Longmu (C1), Aohan (C2) and Zhaodong (C3) and three cutting frequency: 30 (F30), 40 (F40) and 60 day (F60) intervals. The varieties are widely planted in this regions with high yield and favorable adaptability to the Northeast areas of China. Cultivars were sown on 1 May, 2008 in a randomized block design with three replicates. There are 27 plots in this study. Each plot is 3 m long and 2 m wide with inter-row spacing of 15 cm. Seeding rate is 15 kg $ha^{-1}$ and seed were drilled uniformly. After seeding, the plots were compacted using a corrugated roller. Open perimeter area outside of the experiment was reserved to protect the experimental rows from interferential damage. No fertilizer or irrigation was applied during the experimental periods. Plots were hand-weeded during the growing period whenever necessary for proper weed control. The experiment was carried out for 2 consecutive years where cutting frequencies occurred during a 120 days period of each year from June 15 to October 12 except in the establishment year in which the crop was harvested two times determined by the temperature and photoperiod. During experimental period there were 4, 3 or 2 shoot regrowth cycles for the 30, 40 and 60 days treatments (Fig. 2).

**Sampling and analytical methods:** The shoot samples were cut to ground level with manual shears using 0.5×0.5 m quadrats for determination of the variables: shoots/$m^2$ (number of shoots divided by 0.25 $m^2$), mass/shoot (total g of dry matter divided by the number of shoots) and shoot height. Forage yield (g DM/$m^2$) was determined by harvesting 2×2 $m^2$ of each plot (leaving margins and a 5 cm stubble). With forage yield data of each regrowth, the annual forage yield (total yield of all cuttings) and 2 years total forage yield (adding the yield of each regrowth from both years) was calculated. Initial and final plant density was measured by counting plants per plot annually, before the end of April when the beginning of the spring regrowth started. Samples were

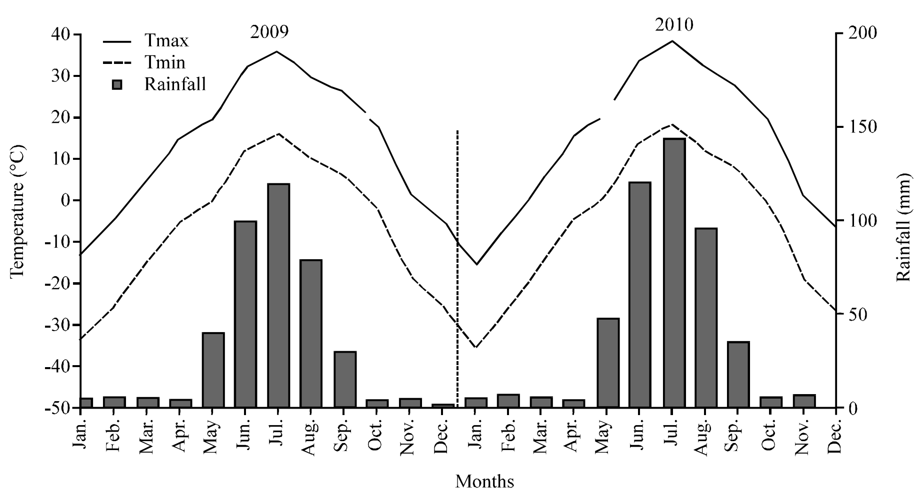


Fig. 1: Monthly average of maximum and minimum temperatures and total rainfall for 2009 and 2010 at Lanxi County, in China

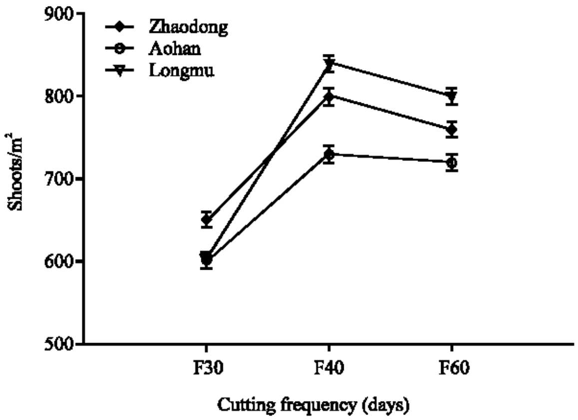


Fig. 2: Average of 2 years (mean±SE) of shoots/m$^2$ of three alfalfa varieties under three cutting frequentcy: F30, F40 and F60

Table 1: ANOVA results on effects of cutting Frequency (F) on forage yield of Cultivars varieties (C) on forage yield over a 2 year period at Lanxi county in China

| | Forage yield (g DM/m$^2$)† | | |
|---|---|---|---|
| Variation¶ | 2009 | 2010 | 2 years total |
| F60 | 520$^b$ | 680$^b$ | 1200$^b$ |
| F40 | 614$^a$ | 852$^a$ | 1466$^a$ |
| F30 | 348$^c$ | 416$^c$ | 764$^c$ |
| Average | 494 | 649 | 1143 |
| LSD (0.05) | 90 | 120 | 246 |
| C1 | 452$^a$ | 714 | 1166 |
| C2 | 436$^{ab}$ | 690 | 1126 |
| C3 | 422$^b$ | 696 | 1138 |
| Average | 437 | 700 | 1143 |
| LSD (0.05) | 42 | NS‡ | NS |

¶The cutting frequency were 30, 40 and 60 day for F30, F40 and F60, respectively. The cultivars varieties were Longmu, Aohan and Zhaodong for C1, C2 and C3, respectively. †Forage yield of each F is averaged across all C and forage yield of each C is averaged across all F. ‡NS indicates no statistically significant difference between group at p≥0.05. Different letters between rows are statistically different at p<0.05

dried in the oven for 72 h at 65°C (Vasilakogloua and Dhima, 2008) then ground with a Wiley mill to pass a 1 mm screen and analyzed for quality components. Crude Protein content (CP) were calculated by the methods of Association of Official Analytical Chemists-AOAC. Neutral Detergent Fibre content (NDF) was determined using the procedure by Goering and van Soest (1970).

The effects of Cultivars (C), cutting Frequency (F) and the interactions between two (C×F) on six trait parameters including shoots/m$^2$, mass/shoot, height/shoot, forage yield (g DM/m$^2$), Crude Protein (CP) and Neutral Detergent Fibre content (NDF) of alfalfa crop were analyzed with one-way ANOVA of General Linear Model (GLM) and a posteriori Tukey-Kramer LSD test ($p<0.05$). Due to a lack of normality, some data were square root transformed as appropriate prior to analysis. Where F-tests were significant ($p<0.05$), LSD was calculated to compare the means. Data were analyzed using the General Linear Models (GLM) procedure. All statistical analyses were performed using Statistical Computer Software SAS (1999).

## RESULTS AND DISCUSSION

**Forage yield:** Although, weather conditions at Lanxi county differed considerably in 2009 and 2010, the alfalfa yield production among the 2 years were relatively consistent. Positive effect of cutting frequency was recorded in 2009 and 2010. The interaction (C×F) also was significant during 30, 40, 60 days regrowth periods in both years ($p<0.05$). In 2009, 2010 and for the 2 years total, F40 had also significantly higher yields than F60 and F30. Cultivars varieties for DM production observed in the experiment did not show significant, difference except in 2009 where C1 had more DM production (452 g DM/m$^2$) than C3 (422 g DM/m$^2$) with C2 being intermediate (436 g DM/m$^2$) (Table 1).

**Shoots/m$^2$:** The significant effect of cutting frequency on shoots/m$^2$ was observed in both years (Table 2) whereas cultivar varieties and the (C×F) interaction for shoots/m$^2$ in 2009 and 2010 were not significant. In 2009 the effect of F on shoots/m$^2$ was observed significantly because the F40 and F60 treatments had higher shoot numbers (743 and 668 shoots/m$^2$, respectively) when compared to F30 (645 shoots/m$^2$) while the effect of C did not show significant difference, although C1 had more shoots (628 shoots/m$^2$) than C3 (586 shoots/m$^2$) with C2 being intermediate (628 shoots/m$^2$). In 2010, F40 and F60 had more shoots (972 and 876 shoots/m$^2$, respectively) than F30 (771 shoots/m$^2$). Total 2 years shoots/m$^2$ for three cultivars in both years were obtained but no difference is statistically significant at the 5% level was observed while C1 (628 shoots/m$^2$) produced more shoots/m$^2$ than C2 (606 shoots/m$^2$) and C3 (586 shoots/m$^2$).

**Mass/shoot:** The significant effect of cutting frequency on mass/shoot was observed in both years (Table 2). The mass/shoot for cutting frequency ranged from 0.27-0.45 g DM in 2009 and from 0.28-0.46 g DM in 2010. In 2009, the effect of F on mass/shoot was observed significantly because the F40 and F60 treatments had greater mass/shoot (0.45 and 0.33 7 g DM/shoot, respectively) when compared to F30 (0.27 g DM/shoot). In 2010, the effect of F on mass/shoot was observed significantly because the F40 and F60 treatments had higher mass/shoot (0.46 and 0.35 g DM/shoot,respectively) when compared to F30 (0.28 g DM/shoot).

Table 2: ANOVA results on effects of cutting Frequency (F) on shoots/m², mass/shoot and height/shoot of Cultivars varieties (C) over a 2 years period at Lanxi County in China

| | Shoots/m² (plant)† | | Mass/shoot (g DM)† | | Height/shoot (cm)† | |
|---|---|---|---|---|---|---|
| Variation¶ | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| F60 | 668[b] | 876[b] | 0.33[b] | 0.35[b] | 75.60[a] | 76.60[a] |
| F40 | 743[a] | 972[a] | 0.45[a] | 0.46[a] | 65.50[b] | 66.20[b] |
| F30 | 645[c] | 771[c] | 0.27[c] | 0.28[c] | 52.50[c] | 51.30[c] |
| Average | 685 | 873 | 0.35 | 0.36 | 64.53 | 64.70 |
| LSD (0.05) | 16 | 3 | 0.10 | 0.10 | 9.66 | 10.00 |
| C1 | 628 | 992 | 0.35 | 0.35 | 61.50 | 61.80 |
| C2 | 606 | 959 | 0.32 | 0.34 | 62.00 | 62.50 |
| C3 | 586 | 967 | 0.33 | 0.33 | 63.20 | 63.00 |
| Average | 607 | 973 | 0.33 | 0.34 | 62.23 | 62.10 |
| LSD (0.05) | NS‡ | NS | NS | NS | NS | NS |

¶The cutting frequency were 30, 40 and 60 days for F30, F40 and F60, respectively. The cultivars varieties were Longmu, Aohan and Zhaodong for C1, C2 and C3, respectively. †Shoots/m², mass/shoot and height/shoot of each F is average across all C and forage yield of each C is average across all F. ‡NS indicates no statistically significant difference between group at $p \geq 0.05$. Different letters between rows are statistically different at $p<0.05$

Although, mass/shoot was differed at cutting frequency significantly ($p<0.05$) but no difference in mass/shoot occurred among C groups where C1 had more mass/shoot (0.35 g DM/shoot) than C2 (0.32 g DM/shoot) with the C1 alfalfa being intermediate (0.33 g DM/shoot). The interaction (C×F) for mass/shootwas significant in the first and the second year, similar results was obtained in both years (Table 2). Total 2 years mass/shoot of cutting frequency in the experiment was significant where the F60 had significantly higher yields than F30 and F40 (Fig. 3). Cultivars varieties for mass/shoot did not show significant difference in either years (Table 2) while C3 (Zhaodong) accumulated more DM per shoot than C1 and C2 (Fig. 3).

**Height/shoot:** Total 2 years varieties for plant height observed in the experiment did not show significant difference in either year while C3 (Zhaodong) had higher plant height than C1 and C2 (Fig. 4). The interaction (C×F) for height/shoot was significant in both 2009 and 2010 (Table 2). While shoot height of all cultivars decreased with cutting frequency treatment in both years where the shoot height had shorter shoots at F30 and F40 compared to F60 ($p<0.05$). Shoots from the F60 treatment were the tallest (75.60 and 76.60 cm) whereas F30 had the shortest (52.50 and 51.30 cm) and those in the F40 treatment were intermediate (65.50 and 66.20 cm). The effect of C did not show significant difference although C3 (Zhaodong) were tallest (63.20 cm in 2009 and 63.00 cm in 2010) whereas C1 (61.50 and 61.80 cm) was the shortest with the C2 being intermediate (62.00 and 62.50 cm).

**Forage quality:** In 2009 F30 presented a higher crude protein (25.50%) than F60 (18.42%) and those in the F40 were intermediate (22.56%) for the three varieties. In 2010,

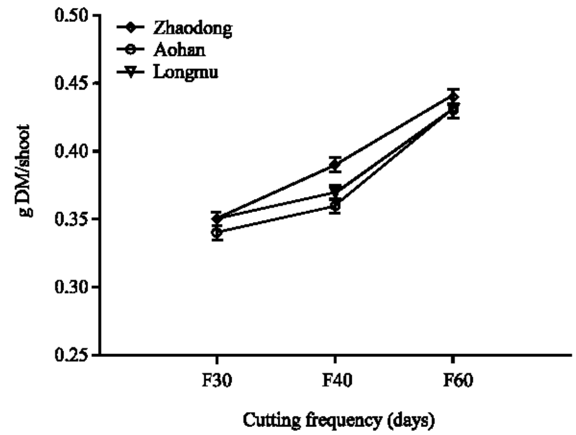


Fig. 3: Average of 2 years (mean±SE) of mass/shoot of three alfalfa varieties under three cutting frequentcy: F30, F40 and F60

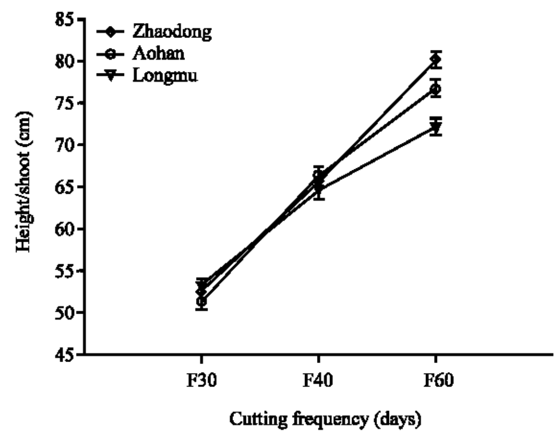


Fig. 4: Average of 2 years (mean±SE) of height/shoot of three alfalfa varieties under three cutting frequentcy: F30, F40 and F60

similar result was observed among F60, F40 and F30 (18.62, 22.70 and 25.33%, respectively). Meanwhile, there was significant interaction between varieties on CP in both years. For the total 2 years, C1 (Longmu) had the highest value than C2 whereas C3 were intermediate (Fig. 5). In 2009 F30 or F40 presented a lower NDF than F60 for the three varieties. In 2010, similar result was observed among F60, F40 and F30 (33.62, 29.70 and 28.33%, respectively). Total 2 years, NDF of C1 (Longmu) had the lowest NDF content than C2 whereas C3 were intermediate (Fig. 6).

In forage production, a major goal is to increase herbage yield (Wang *et al*., 2009). During the two production years, annual mean temperatures in each year were equivalent to the long-term average but there were more rainfall events and total precipitations in 2010.

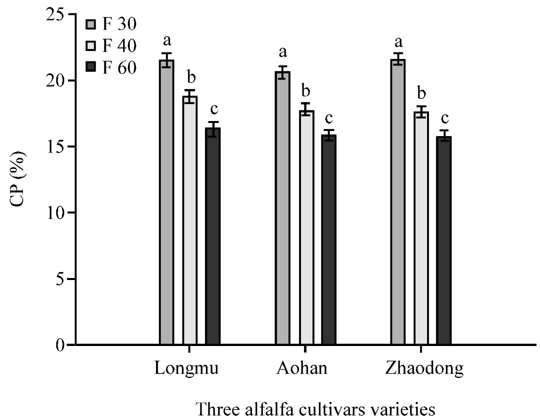


Fig. 5: Average of 2 years (mean±SE) of total crude protein (CP, %) of three alfalfa varieties under three cutting frequentcy: F30, F40 and F60

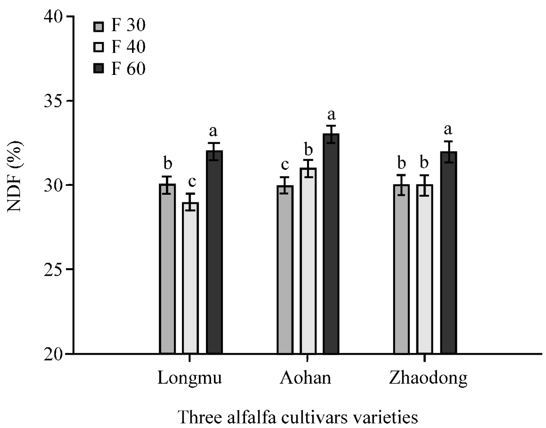


Fig. 6: Average of 2 years (mean±SE) of total neutral detergent fibre content (NDF, %) of three alfalfa varieties under three cutting frequentcy: F30, F40 and F60

Although, there were not large deviations in monthly mean temperatures and accumulated rainfalls during the growing season from year to year, these weather variations were part of the reasons of annual total DM yield differences of the same varieties. In alfalfa, forage yield was thought to be associated with variety. There were several studies illustrating the relationship in temperate regions with mild climate (Barnes *et al*., 1979; Stout and Hall, 1989). However, few studies investigated the relationship between cultivars with different fall dormancy ranking on forage yields (Li and Zhu, 2005; Wang *et al*., 2005).

In this study, the highest alfalfa yield, shoots/m$^2$ and mass/shoot occurred at F40 and the lowest crop yield, shoots/m$^2$ and mass/shoot was at F30 indicating the F40 are most suitable for alfalfa growth in the temperate Northern regions. Among the three varieties, the greatest DM yield was obtained from the C1 (Longmu), followed by the C2 and C3 had the lowest yield. This is in accordance with the findings of other studies in the regions with similar climate (Han *et al*., 2004; Wang *et al*., 2004).

The interaction between cultivar and cutting (C×F) on annual and 2 years total forage yield was not significant (Table 1) which is consistent with those of similar studies on alfalfa yield in Australia (Lodge, 1986) and in USA (Kallenbach *et al*., 2002). The results showed that the anterior had a greater effect on forage yield which agrees with results of others (Putnam and Orloff, 2003; Putnam *et al*., 2005). The decreased forage yield with cutting frequency was due to the decrease in shoots/m$^2$ (Undersander *et al*.,1998), mass/shoot (Berg *et al*., 2005, 2007) and height/shoot (Griggs and Stringer, 1988). The decrease in these yield components could be due to a reduction in the amount of energy captured through photosynthesis, especially for a shorter regrowth length (F30) and a decrease in taproot organic reserves (Teixeira *et al*., 2007a), mainly nitrogen reserves (Avice *et al*., 1996). This reduction in reserves would have a negative effect on radiation use effciency at the whole plant level because of a decline in photosynthetic capacity of the youngest initiated leaves post-defoliation (Teixeira *et al*., 2008) which together with subsequent reductions in canopy expansion rates (Teixeira *et al*., 2007c) diminished forage yield.

The largest annual forage yield difference of C1 vs. C3 was mainly explained by the greater mass/shoot and height/shoot of the nature of the cultivar. In 2010, there was no statistical difference in annual forage yield among cultivars which showed no difference in mass/shoot, height/shoot. Therefore, the results of both years indicated that differences in forage yield ranking among cultivars can change with time which agrees with the results of Ventroni *et al*. (2010). The range of shoot density obtained in the current experiment (336-700 shoots/m$^2$) was similar compared to those of Cangiano and Pece (310-910 shoots/m$^2$) but lower than the density in the experiments undertaken by Teixeira *et al*. (2007b) (780-900 shoots/m$^2$) using broadcast-seeded plots. The results confirmed increased cutting frequency caused a reduction in mass/shoot as reported by Teixeira *et al*. (2007b). Shoots/m$^2$ was reduced with increased cut frequently which is in agreement with Nelson *et al*. (1986).

In the current experiment, shoots/m$^2$ and mass/shoot both declined for all three cutting frequencies and resulted in the lowest forage yield for F30. There was no compensation between yield components. Conjectural reasons reported by Teixeira *et al.* (2007c) were that grazing alfalfa affected only canopy expansion rates compared with canopy architecture traits and development processes of canopy formation (leaf appearance, branching and shoot initiation). Therefore, it follows that alfalfa might have little plasticity among yield components where frequent defoliation increased tiller, diminished tiller mass and resulted in no net change in forage yield (Chapman and Lemaire, 1993).

To find appropriate cutting frequency to achieve trade-off of higher quality and yields, researches had demonstrated that fertilization had significant effect on compensatory growth after cutting and increased forage fresh yield (Lithourgidis *et al.*, 2006) and reduced yield loss from cutting (Ross *et al.*, 2005). The present study results showed that forage yield decreased and forage quality improved for F40 which is consistent with other researches that cutting had significant effects on forage quality and yields (Chen *et al.*, 2003; Yang *et al.*, 2004). In this study, Longmu presented best response on CP and NDF at F40 utilization, Zhaodong was the next best. Therefore, Longmu appeared to give a higher dry hay yields than the other two varieties under F40 conditions due to maximum compensatory growth.

## CONCLUSION

The study provides evidence that 40 days intervals can be advocated for cultivars growing in Northeast area of China and Longmu is a well-adapted alfalfa variety in the Songnen Plain at F40 utilization because of higher hay yield and quality under three cutting frequentcy. Therefore, further study should be conducted to seek optimal management practices to increase yield component and achieve the trade-off of higher quality and greater yields under proper management methods.

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