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Full Length Research Paper

Effects of mowing utilization on forage yield and quality in five oat varieties in alpine area of the eastern Qinghai-Tibetan Plateau

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Oat (*Avena sativa*) is grown to provide feed in winter for livestock production in the alpine area of Qinghai-Tibetan Plateau. The effect of early cutting (T1), late cutting (T2) as well as once cutting and twice cutting (T3) on forage yields and qualities were investigated for five oat varieties (*YTA*, *CNC*, *B3*, *Q473* and *Q444*). The cutting frequency and time significantly affected forage yield and quality of five varieties with the effects being different among the five varieties. T3 increased hay yield and crude protein yield than T2. The dry hay yield and crude protein yield of T2 were all significantly lower when compared to T1. *YTA* presented the maximum fresh grass yields, total hay yields and total crude protein yields under all cutting treatments among five varieties. T3 also improved feed quality on S/L ratio, F/D ratio, CP, CF and CA compared to T2 treatment. The results showed that utilization of two cuttings of oat artificial grasslands can be used to supply forage for livestock in alpine area. *YTA* is a good oat introduced variety which has higher hay yield and feeding quality even with two cuttings in alpine area.

Key words*:* *Avena sativa* L., mowing, yield, oat, quality, Qinghai-Tibetan Plateau.

INTRODUCTION

Oats (*Avena sativa.*) have historically been a widely used food and forage crop all over the world (Moreira, 1989; Zhang et al., 1998; Wu, 2007). Oaten hay has been widely used in the high-cold regions of the Qinghai-Tibetan Plateau (Long, 1995; Dong et al., 2003; Wu, 2007) as a source of roughage for dairy cattle and to improve livestock production. In the traditional alpine farming systems of the Qinghai-Tibetan Plateau, insufficient feed in the winter season seriously limit the productivity of livestock grazed on natural grasslands year round (Long, 1995; Dong et al., 2003). Oats would potentially have a beneficial impact on livestock husbandry in such farming systems but significant gaps in current knowledge exist, e.g. appropriate frequency of mowing, time of mowing and post-harvest processing techniques. In recent years, the planting of oats in alpine areas had played an important role in eliminating the seasonal imbalance between livestock and forage production. The use of oats had also increased the vegetation cover, prevented the degradation of grassland and assisted the sustainable development of livestock production in alpine farming systems (Wu, 2007). In recent years, however, increasing degradation of grasslands due to increasing livestock numbers has restricted the grazing in the alpine area of the Qinghai-Tibetan Plateau.

Previous studies of oats as a forage mainly focused in yield and adaptability of oat varieties introduced into the alpine area (Kang et al., 2000). Oat yields increased with the successive growth stages: jointing, boot, heading, milk and dough stages. The crude protein content of forage usually was considered as one of the most important criteria for forage quality evaluation (Caballero

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et al., 1995). So, the quality of oaten hay was important for livestock feeding (Wu, 2007). Oat usually reached its maximum yield at flowering stage and it had optimal feeding quality at booting stage (Yang and Hu, 1991). Researchers had found that, harvest time can affect forage yield and quality for cereal–legume intercrops (Roberts et al., 1989; Ghanbari-Bonjar and Lee, 2003). Additionally, oat showed compensatory responses to cutting in many conditions (Chen et al., 2003; Lei et al., 2005). So, further researches on quality and yield response to mowing time are needed for advanced utilization efficiency by reasonable utilization modes.

In this study, the investigation of forage yield and quality of five oat varieties under different harvest time and frequency management was carried out to: (1) com-pare the forage yield and quality response of five oat varieties to cutting time and frequency; (2) find out if these varieties had higher yield and quality at the second cutting under two harvest mode and an effective oat forage cutting utilization mode and some high-yield oat varieties were found in alpine area of the Qinghai-Tibetan Plateau.

MATERIALS AND METHODS

Study site

The field experiment was conducted at Maqu, Gansu Province, China (altitude 3460 m, 102°53′E, 34°55′N) in 2008. All seeds were sown on an experimental field which is situated in the northeast margin area of the Qinghai-Tibetan Plateau. Average annual temperature is 2.0°C with the lowest daily temperature averaging –8.9°C and concentrated in December, January and February. The highest daily temperature averages 11.5°C and was concentrated in June, July and August. The average precipitation of a year is 550 mm and was concentrated in July, August and September. The vegetation typifies alpine meadow (Wu, 1995). Abandoned farmland which had been ploughed was selected as study site for oat planting. The soil type of the experimental site was an alpine soil with high melanic humus. The experimental area had mean soil pH of 7.59, mean soil organic matter content of 5.04%, total N content of 0.24%; the contents of NO^{-}_{3}-N was 4.25%, the contents of NH^{+}_{4}-N was 6.51% and available P was 22.75 ppm.

Field experiments

Five precocious oat varieties (*YTA*, *CNC*, *B3*, *Q473* and *Q444*) which were cultivated and planted widely and had showed high seed production, high yield and stronger adaptability in alpine area of the Qinghai-Tibetan Plateau (Kang et al., 2000; Shi et al., 2003) were used in this study. The *YTA* and *CNC* varieties were gathered from Finland and Canada, respectively. The *B3*, *Q473* and *Q444* varieties were gathered from the Qinghai Province. Additionally, oats usually had optimal feeding quality at booting stage and maximum yield at flowering stage (Brundage and Klebesadel, 1970; Yang and Hu, 1991). Meanwhile, light mowing at early growth stage was in favor of compensation growth of *Avena sativa* (Chen et al., 2003). Moreover, the plant has shorter growth period and life cycle in alpine area of the Qinghai-Tibetan Plateau because of cruel climate conditions. Several-fold harvest will limit its natural growth and yield. So three harvest treatments was set up in this study: T1, T2 and T3, where T1 treatment was harvested at booting stage on 25 June and stubble height was 4 cm, T2 treatment was harvested at the last growth stage on 15 August and T3 was harvested two times on 25 June and 15 August which is T1 + T2. A randomized block design was used to set up the plots in this study. The study was set up with three sampling plots of 2 × 3 m for each harvest treatment of each variety and five quadrats (50 × 50 cm) per each plot. Fifteen quadrats from each harvest treatment of each variety were measured. The seeds were drilled in rows at 15 g/m^2 with a row spacing of 15 cm in early April 2008. Weeds were removed once during the growing period. They were watered once each month during the experimental periods. Di-ammonium phosphate (DAP) was used as a pre-treatment fertilizer at a rate of 22.5 g/m^2. Fertilizer was applied again to all plots at the tillering stage of oat growth at a rate of 15 g/m^2. In addition, weeding was carried out twice (young seedling stage and earlier vegetative stage) and the oats irrigated at the three most important stages of growth (tillering, jointing and booting).

Forage hay yields (dry grass yield), stem/leaf ratio, fresh/dry ratio and nutrient contents were measured. Plants were cut to ground level with manual shears and separated by hand for determination of fresh grass weight. Forage yield was determined by harvesting 50 × 50 m of each plot, approximately 4 cm above the soil surface. Five individual random samples were selected from each quadrats. Then they were taken back to laboratory and the dry-matter yield and fresh/dry ratio were obtained. For forage quality at harvest, a second set of random samples of 1 kg biomass from each plot was taken and prepared for chemical and nutrient analysis. All samples were dried in the oven for 72 h at 65°C (Vasilakogloua and Dhimab, 2008). The samples were ground with a Wiley mill to pass a 1 mm screen and analyzed for quality components. Forage quality was measured in the laboratory by proximate analysis. Crude protein content (CP), crude fat content (CF), crude ash content (CA) were calculated by the methods of Association of Official Analytical Chemists -AOAC (1980). Acid detergent fibre content (ADF) was determined using the procedure by Goering and Van Soest (1970). The crude protein yields (CPY) were calculated as hay yields × crude protein content (CP).

Statistical analysis

The fresh and hay yields for T3 treatment were the sum of twice harvests. Other parameters were measured by results of the second harvest. The effects of harvest treatment, variety and their interaction on hay yield (HY), crude protein yields (CPY), stem/leaf ratio (S/L ratio), fresh/dry ratio(F/D ratio), crude protein content (CP), crude fat content (CF), crude ash content (CA) and acid detergent fibre content (ADF) of oat forage were analyzed with two-way ANOVA of General Linear Model (GLM) and a posteriori Tukey-Kramer HSD test ($P < 0.05$). All data were analyzed with statistical computer software SPSS v. 12.0.

RESULTS

Forage yield

The results of ANOVA analyses showed that there were significant effects of harvest treatments ($P < 0.001$) and varieties ($P < 0.001$) and their interaction on fresh grass yield (FY), hay yield (HY), crude protein yields (CPY) (Table 1). Biomass of HY and CPY presented a signify-cant increase under T2 treatment than T1 treatment for five varieties. T3 treatment significantly increased yield of HY and CPY than T2 treatment, except for HY of *Q473*

Table 1. ANOVA results on effects of harvest treatments, variety and their interaction on fresh grass yield (FY), hay yield (HY), crude protein yields (CPY), stem/leaf ratio (S/L ratio), fresh/dry ratio(F/D ratio), crude protein content (CP), crude fat content (CF), crude ash content (CA) and acid detergent fibre content (ADF).

Parameters	Harvest treatments			Variety			Harvest treatments × Variety		
	d.f.	*F*	*P* Value	d.f.	*F*	*P* Value	d.f.	*F*	*P*-Value
FY	2	96.436	0.000	4	26.237	0.000	8	3.026	0.013
HY	2	792.226	0.000	4	233.816	0.000	8	74.967	0.000
CPY	2	705.304	0.000	4	139.714	0.000	8	30.944	0.000
S/L ratio	2	22.118	0.000	4	80.857	0.000	8	71.744	0.000
F/D ratio	2	251.134	0.000	4	5.150	0.003	8	5.742	0.000
CP	2	228.540	0.000	4	6.885	0.000	8	10.104	0.000
CF	2	58.393	0.000	4	9.693	0.000	8	13.430	0.000
CA	2	189.350	0.000	4	38.915	0.000	8	5.624	0.000
ADF	2	85.544	0.000	4	9.277	0.000	8	2.457	0.035

Significant level is $P < 0.05$.

and CPY of *Q444*. Especially for *YTA*, its HY and CPY enhanced 60 and 25% under T3 treatment than T2 treatment, respectively *B3* and *CNC* also presented the bigger increase (Figure 1a and b).

Forage quality

Results showed that harvest treatments and varieties significantly affected values of stem/leaf ratio (S/L ratio), fresh/dry ratio (F/D ratio), crude protein content (CP), crude fat content (CF), crude ash content (CA) and acid detergent fibre content (ADF). Meanwhile, there were significant interaction effects between harvest treatments and varieties on these forage quality parameters (Table 1). T1 presented a higher forage quality than T2 for the five oat varieties: T1 followed a lower S/L ratio and a higher F/D ratio than T2, except for *CNC*. T3 also decreased S/L ratio and increased F/D ratio for *YTA*, *B3*, *CNC* and *Q444* than T2 treatment (Figure 2a and b). These advanced the forage palatability. Meanwhile, there were lower CP CF and CA and higher ADF under T2 than T1 treatment. T3 showed an increased CP, CA and ADF and decreased CF than T2 (Figure 2c, d, e and f). Early cutting showed a higher feed quality than later cutting. Meanwhile, T3 also improved feed quality than T2 in S/L ratio, F/D ratio, CP, CF and CA.

DISCUSSION

The present results indicated that early cutting utilization usually followed a higher feed quality and a lower yield. However, twice cutting utilization significantly increased oat hay yield, crude protein yields and other quality contents than once cutting utilization. So, it was found that the first cutting of twice utilization provided high-quality forage for livestock and twice cutting utilization brought total higher-yield forage hay. Meanwhile, the second cutting of twice utilization mode also improved forage quality than once cutting utilization. Possible interprettation is compensatory growth of plant after cutting and cutting restrain its reproductive growth to invest more resources to nutrient component. Lei et al. (2005) reported that the low-frequency cutting at the nutrition stage were more beneficial to compensatory growth of oat in alpine area. But no information on the optimal timing for these forage plants was reported. More study need to be conducted to find appropriate cutting frequentcy and time to achieve trade-off of higher quality and yields. In addition, researches had demonstrated that fertilization had significant effect on compensatory growth after cutting and increased oat fresh yield (Lei et al., 2005) and oat intercropping with leguminous species (e.g. berseem clover) could produce greater oat forage yield (Lithourgidis et al., 2006) and reduce yield loss from cutting (Ross et al., 2005). So, some more agricultural and management methods should be conducted to improve forage yield and quality when it is cutting utilization time after time.

The present results showed that oat forage yield decreased and forage quality improved with late cuttings, which were in accordance with some other researches that cutting had significant effects on forage quality and yields (Chen et al., 2003; Yang et al., 2004). Meanwhile, different varieties showed different response for forage yield and quality to cutting. Some researchers have reported that *Q473* and *Q444* had high yield and strong adaptability in alpine areas (Kang, 2000), however, the present results showed that *Q473* and *Q444* had significantly decreased yield when used by two cuttings. These were not propitious to being planted for higher hay yield even with higher cutting frequency in alpine areas. In this study, *YTA* presented best response on yield and crude protein yield to twice cutting utilization, *B3* and *CNC* were next. *YTA* appeared to give the higher dry hay

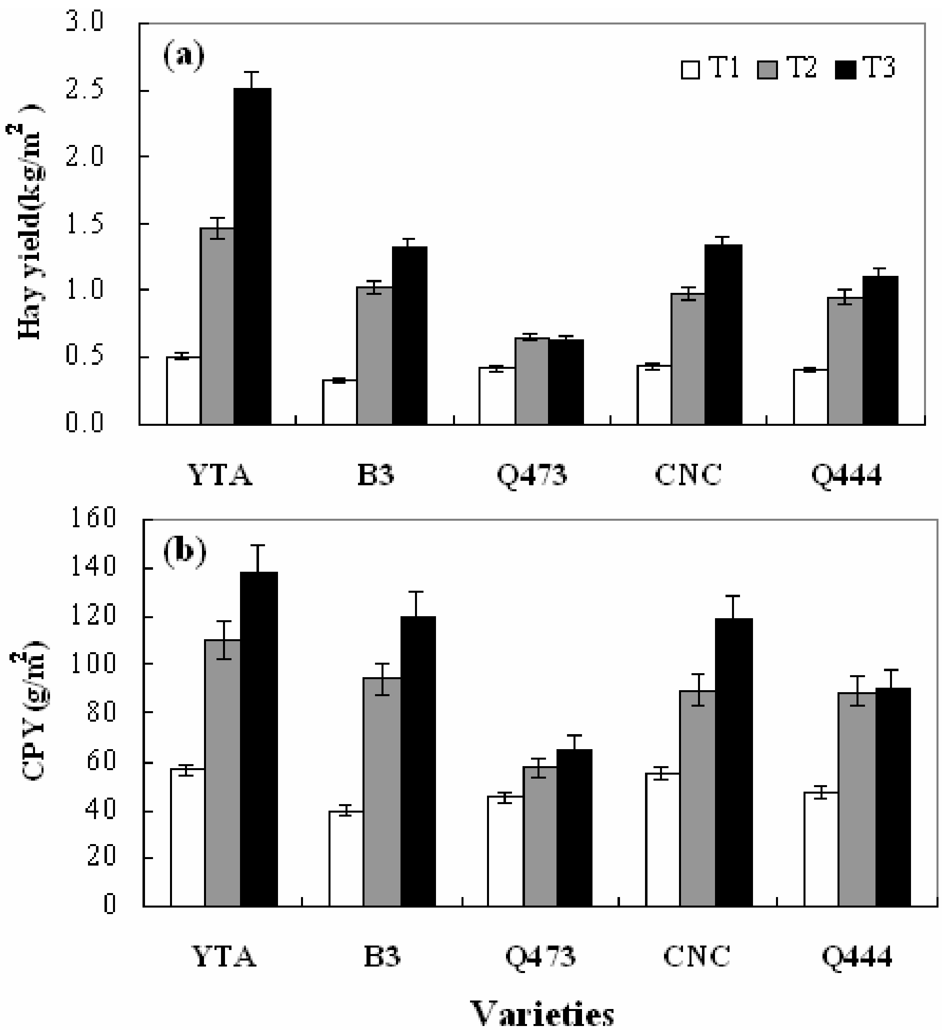

Figure 1. Mean value (± SE) of total hay yield (HY, a) and total crude protein yields (CPY, b) of five oat varieties under three-harvest treatments: T1, T2 and T3. where T1 treatment was harvested at booting stage on 25 June; T2 treatment was harvested at the last growth stage on 15 August and T3 treatment is harvested two times on 25 June and 15 August which is T1 + T2, the data was sum of twice harvest.

dry hay yields than the other four varieties under twice cutting conditions. *YTA* presented the maximum compensatory growth under both the first and the second cutting among five varieties. They kept higher forage yield and quality under twice cutting utilization. So, these three oat varieties were better forge varieties which were fit for cutting utilization time after time in alpine area.

Conclusion

In general, twice cutting utilization effectively advanced total yield and feeding values of oat forage in alpine area. *YTA* is a well-adaptability oat variety in alpine area of the Qinghai-Tibetan Plateau, because it had higher hay yield and feeding quality under twice cutting utilization. Further study should be conducted to seek optimal cutting frequency and time to achieve the trade-off of higher quality and greater yields under proper management methods.

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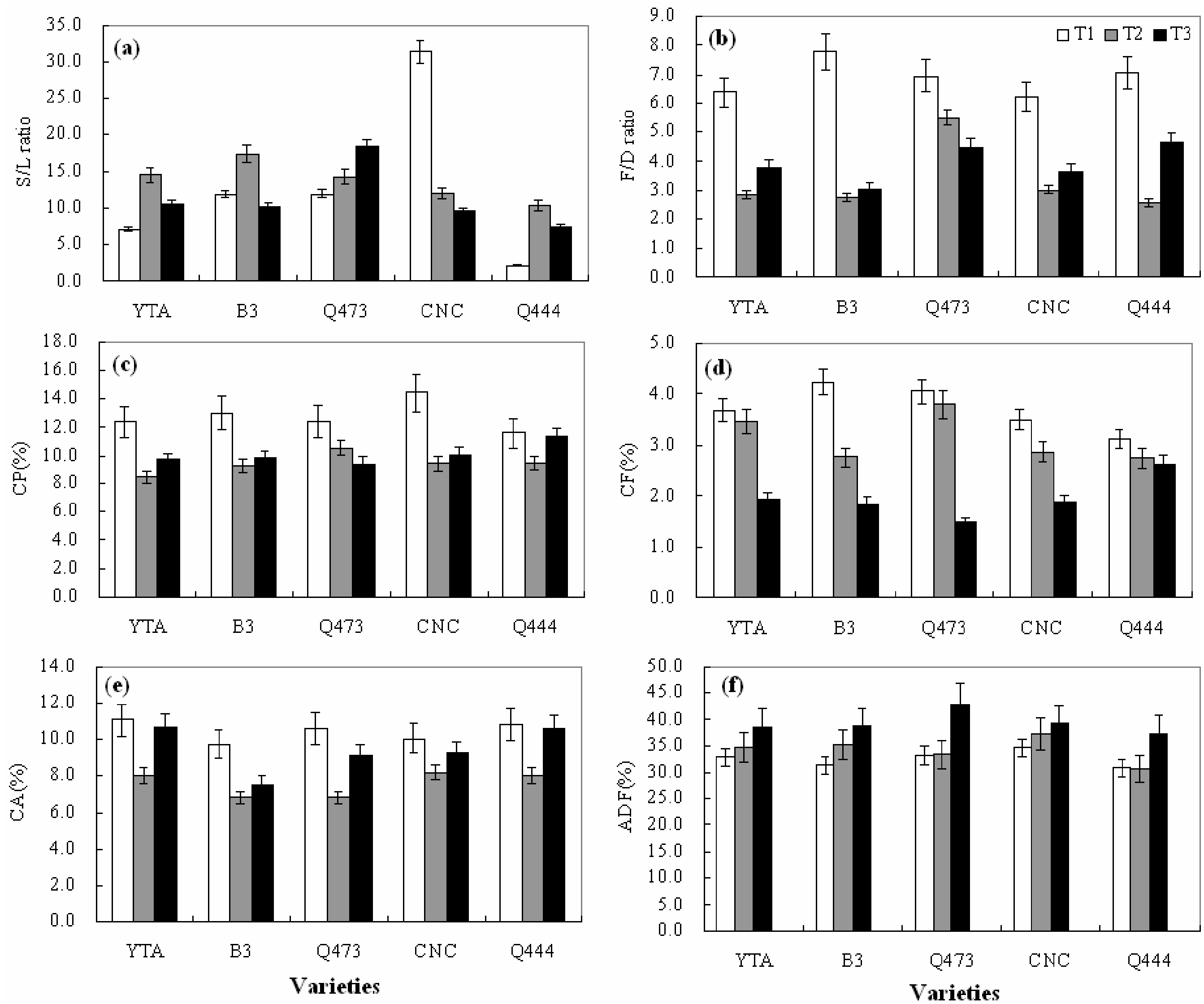

Figure 2. Mean forage qualities values (± SE) of five oat varieties under three-harvest treatments: T1, T2 and T3. The data of T1 and T2 was the same with Fig. 1, but the data of T3 was the data of the second harvest in this treatment. The grass qualities contain stem/leaf ratio (S/L ratio, a), fresh/dry ratio (F/D ratio, b), crude protein content (CP, c), crude fat content (CF, d), crude ash content (CA, e), acid detergent fibre content (ADF, f).

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