Dry matter yield and nutritive value of forage crops under different rotations on the Longdong Loess Plateau, China

Yining Niu [1], Zhibiao Nan [1], **William Bellotti [2],** Jeremy Whish [3], Lindsay Bell [3]

[1] College of Pastoral Agriculture Science and Technology, Lanzhou University, Lanzhou, Gansu 730000, China, www.lzu.edu.cn Email niuyn06@lzu.cn
[2] School of Natural Sciences, University of Western Sydney, Email w.bellotti@uws.edu.au
[3] Commonwealth Scientific and Industrial Research Organisation, Email Jeremy.Whish @csiro.au

Abstract

The object of this experiment was to compare the dry matter yield and the nutritive value of forage crops under different rotation sequences on the Longdong Loess Plateau of China. There were four introduced forage crops: forage maize (*Zea mays* L.), sudan grass (*Sorghum sudanense* Stapf), proso millet (*Echinochloa crusgalli var. frumentacea*) and oats (*Avena sativa* L.) with four local crops: foxtail millet (*Setaria italica*), common vetch (*Vicia sativa*), mixed crop (maize, millet and sorghum sown together, a traditional livestock feed source) and lucerne (*Medicago sativa* L.) were trialled. These eight crops were grown in five rotation treatments: maize-vetch-oats rotation (MVO), sudan grass-vetch-oats rotation (SVO), proso-vetch-oats rotation (PVO), millet-vetch-mixed crop rotation (MVM) and perennial lucerne field (Lucerne). The dry matter yield over 2 years averaged 9.5 t ha^{-1} $year^{-1}$ for maize, 5.8 t ha^{-1} $year^{-1}$ for sudan grass, 5.4 t ha^{-1} $year^{-1}$ for oats and 4.0 t ha^{-1} $year^{-1}$ for proso. The mixed crop had the lowest average yield (2.1 t ha^{-1} $year^{-1}$). The MVO rotation had the highest DM yield (average 7.4 t ha^{-1} $year^{-1}$). Compared to the PVO rotation, the SVO rotation had a higher DM yield (5.6 t ha^{-1} $year^{-1}$), but a lower nutritional yield. The lucerne treatment had the highest crude protein yield compared to the other rotation treatments. The result showed that maize, proso and oats were productive forage options, especially oats are good summer forage in the region. The MVO and PVO rotations are the optimum rotation in the region. Introduced annual forage crops into current farming system could help reduced feed deficits for livestock producers.

Key Words

Forage crops, dry matter yield, nutritive value, Longdong Loess Plateau.

Introduction

In China animal feed supply is a key constraint to improving livestock production (Devendra and Sevilla, 2002; Devendra, 2007; Salem and Smith, 2008). The Longdong Loess Plateau, located in north-western China, is characterized by its semi-arid climate and mountainous terrain. The farming systems are primarily subsistence, with livestock being the main source of farmer income. A project funded by the Australian Centre for International Agricultural Research (ACIAR), was initiated in 2008, named ‘Improving farmer livelihoods through efficient use of resources in crop-livestock farming systems in western China’. One project objective was to focus on developing better livestock feeding systems. Previous research in the region showed that current livestock production systems have two tonne feed deficit on average (50% deficit of the livestock demand over the year) per year in each household (our unpublished data). The objective of this paper was to measure the introduced forage dry matter yield and nutritive value of different rotation systems. Understanding these yields and nutritive values can help to increase the livestock feed supply and improve livestock production.

Methods

Field description

The experimental site was located on the Quzi Trial Station (36?20?N, 107?21?E; elevation 1163 m a.s.l.) Lanzhou University, 39 km south of Huanxian county, Gansu province, in the Longdong Loess

Plateau, China. The trial was carried out in 2008 and 2009 with the rainfall being 380 and 283 mm, respectively. The soil was a Huangmian soil of loess deposits with pH 8.5, organic carbon 5 g kg^{-1}, total nitrogen 0.7 g kg^{-1}, and particle size distribution of > 0.05mm = 20.4%, 0.05 - 0.02 mm = 63.1% and < 0.02 mm = 16.5%.

Experiment design and treatments

The experiment was a complete randomized block design. There were eight forage crops trialled in this experiment: forage maize (*Zea mays* L.), sudan grass (*Sorghum sudanense* Stapf), proso millet (*Echinochloa crusgalli var. frumentacea*), foxtail millet (*Setaria italica*), common vetch (*Vicia sativa*), oats (*Avena sativa* L.), mixed crop (maize, millet and sorghum sown together, a traditional livestock feed supply resource) and lucerne (*Medicago sativa* L.). These eight crops were grown in five rotation treatments: maize-vetch-oats rotation (MVO), sudan grass-vetch-oats rotation (SVO), proso-vetch-oats rotation (PVO), millet-vetch-mixed crop rotation (MVM) and perennial lucerne field (Lucerne). Each treatment was replicated four times with all phases of the rotation being represented in each year except the lucerne treatment that sown in 2008. Maize, sudan grass, proso, millet and vetch were sown in spring (April) and harvested in autumn (October), except the vetch harvested in summer (July). Oats and mixed crop were sown after vetch and harvested in autumn (October, Table 1). The plot size was 10 m ?15 m.

Table 1. Crop rotation sequence

Year	2008				2009			
Season	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Rotation								
MVO		Maize		Fallow	Vetch	Oats		Fallow
	Vetch	Oats				Maize		
SVO		Sudan grass			Vetch	Oats		
	Vetch	Oats				Sudan grass		
PVO		Proso			Vetch	Oats		
	Vetch	Oats				Proso		
MVM		Millet			Vetch	Mixed crop		
	Vetch	Mixed crop				Millet		
Lucerne				lucerne				

Forage crops were sown by hand with a row spacing of 40 cm. At crop sowing, urea was applied at 69 kg N ha^{-1} and superphosphate applied at 23 kg P ha^{-1}. Another 69 kg N ha^{-1} of urea was applied to maize at jointing time. Weeds were controlled by hand.

Forage crop Measurements

When harvesting the plots for dry matter yield, the crops were at various stages of development. Maize was at reproductive maturity (therefore grain and straw were record separately), proso, sudan grass, lucerne and oats were at anthesis, and the growing stage varied for the mixed crop (all were about 60 cm in height). A sub-sample was oven-dried at 60^oC to constant weight and stored for chemical analysis. Grain and straw components of maize were analysed separately and then calculated for the whole plant. Forage concentration of total nitrogen (TN) (Leco, total combustion AOAC 968.06), neutral detergent fibre (NDF) and acid detergent fibre (ADF) (Robertson and Van Soest, 1981), and *in vivo* digestibility (DOMD)(Roughan and Holland, 1997) were measured. Forage crude protein (CP) concentration was estimated as 6.25?TN concentration. Metabolizable energy (ME) concentration was determined using the following formula:

ME = 0.16 ? DOMD (%).

Statistical analysis

Data were analyzed in Genstat 8.1 with an analysis of variance (ANOVA) using completely randomized design. Because vetch performed poorly in the experiment, the vetch yield was excluded from the total rotation yield.

Results

Crop dry matter yields and nutritive value

There were significant differences of crop dry matter yield between 2008 and 2009 (data not shown). The averaged crop dry matter yield over the two years is shown in Figure 1. Maize has the highest dry matter yield of 9.5 t ha^{-1} $year^{-1}$, followed by Sudan grass (5.8 t ha^{-1} $year^{-1}$), oats (5.4 t ha^{-1} $year^{-1}$), proso (4.0 t ha^{-1} $year^{-1}$), millet (3.7 t ha^{-1} $year^{-1}$), lucerne (3.4 t ha^{-1} $year^{-1}$) and mixed crops (2.1 t ha^{-1} $year^{-1}$).

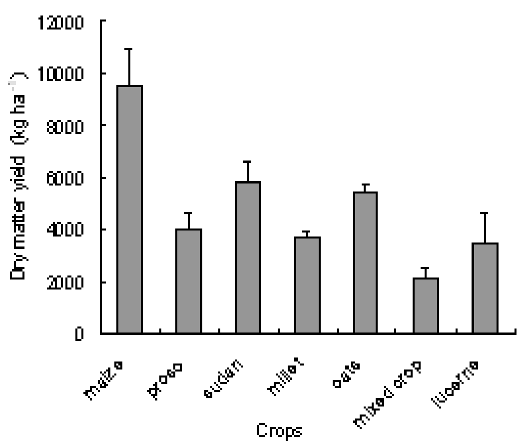

Figure 1. Average forage crop dry matter yield over 2008 and 2009 (? standard error, means followed by the same letter are not different at the 5% significance level)

The forage crops nutritive value differed statistically (*P*<0.05) for almost all the nutritional characteristics (Table 2). Lucerne had the highest CP content, being 1.8 times higher than the mixed crop (*P*< 0.001). Of the annual crops, CP content was highest for proso, then oats, sudan grass, maize and millet. Mean ADF and NDF concentration was highest for millet (361 and 653 g kg^{-1} respectively), while lucerne had a lower ADF and NDF content (262 and 401 g kg $^{-1}$ respectively). For the ME content, maize had the highest value (10.5 MJ kg^{-1}) among the planted crops, this was a consequence of high ME content of the maize grain. Lucerne has the significant difference of ME content with the other crops except mixed crop. Millet had the lowest ME content as it had the lowest CP.

Table 2. Mean concentration of crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and metabolizable energy (ME) in the different crops. Means followed by the same letter are not different at the 5% significance level

Crop	CP (g kg $^{-1}$)	ADF (g kg $^{-1}$)	NDF (g kg $^{-1}$)	ME (MJ kg $^{-1}$)
Lucerne	203^{a}	262^{d}	401^{f}	9.8^{bc}
Mixed crop	111^{b}	262^{d}	494^{d}	9.6^{cd}
Proso	98^{c}	328^{c}	602^{c}	8.9^{e}
Oats	83^{d}	267^{d}	469^{e}	9.5^{d}
Sudan	82^{d}	342^{b}	610^{b}	8.5^{f}
Maize[1]	68^{e}	201^{e}	403^{f}	10.5^{a}
Millet	59^{f}	36.1^{a}	65.3^{a}	8.0^{g}

1 Whole plant, including grain and stalk

Crop rotation system dry matter and nutrition yields

The MVO system had the highest dry matter production (7.4 t ha^{-1} year^{-1}), followed by SVO (5.6 t ha^{-1} year^{-1}), PVO (4.8 t ha^{-1} year^{-1}), lucerne (3.4 t ha^{-1} year^{-1}) and MVM (2.9 t ha^{-1} year^{-1}) rotation (Figure 2).

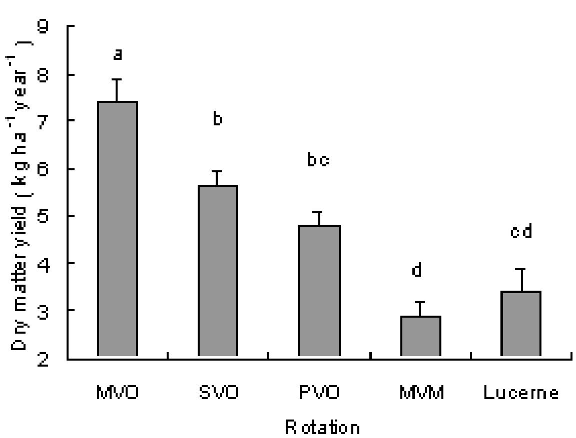

Figure 2. Average forage crop rotation system dry matter yield over 2008 and 2009 (? standard error, means followed by the same letter are not different at the 5% significance level)

Lucerne produced a high crude protein yield (699.8 kg ha^{-1}) in the rotation system and was significantly different (P < 0.05) from other crops (Figure 3). There were no significant differences among the MVO, PVO and SVO rotations for CP yield, MVM rotation had the lowest CP Yield (224.8 kg ha^{-1}).

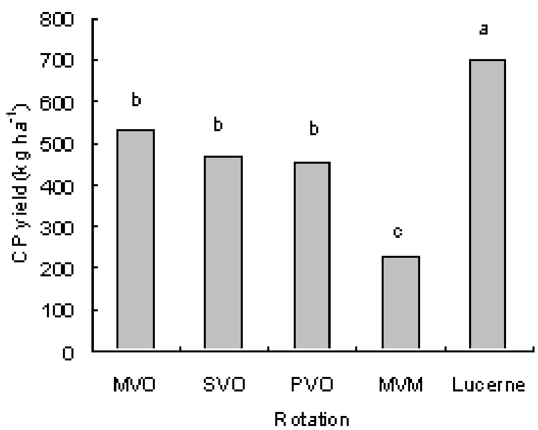

Figure 3. Mean yield of CP under different rotations, 2008 and 2009. Means with the same letter were not significantly different (P<0.05)

There were similar trend for the ADF and NDF yield under different rotations (Figure 4). MVO and SVO rotation system had higher ADF/NDF yield than the other rotations, but the ADF and NDF yield of lucerne was the lowest. MVM rotation had the ME yield 74.3 GJ ha^{-1}, it was significant deference (P < 0.01) than the other rotations (Figure 4).

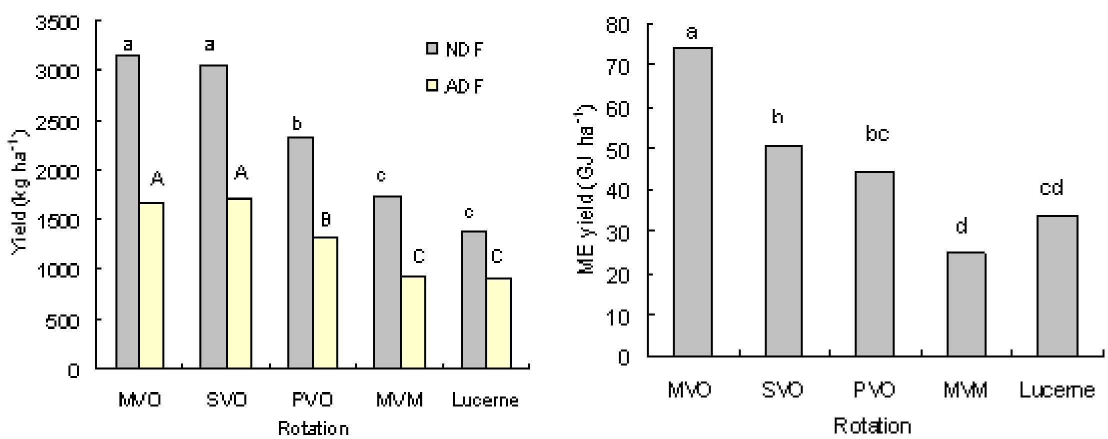

Figure 4. Mean yield of NDF, ADF and ME under different rotations over 2008 and 2009. (Means followed by the same letter are not different at the 5% significance level)

The PVO rotation had a lower ADF and NDF yield (Figure 4) as well as CP yield (P >0.05, Figure 3) than rotations including sudan grass or maize, it appeared PVO rotation more profitable than the other annual crop rotations. On the other hand, the MVM rotation produced more ME yield compared to the other rotations, this was a consequence of high ME content of the maize grain, which was the main ME supplement source in the region for the livestock.

Conclusion

Maize had the highest dry matter yield and metabolizable energy concentration among the introduced forages. Lucerne had the highest CP content, can be used as the main source of the CP nutrition. Proso and oats performed well in the region compared to the mixed crop and millet, especially oats, as it produced a high yield in a short growing season (4 months). If oats is sown after winter wheat under current farming system, the livestock feed deficit will be reduced by one tonne. The introduced annual crops rotated with oats are the optimum rotation in the region.

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