Production and nutritive value of alternative annual forage crop options in a rainfed region of western China

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Abstract

Alternative annual forage crop options could play a useful role in contributing to the feed-base of grain-livestock systems in dryland regions of Gansu province, China. Seasonal dry matter dynamics, WUE and forage nutritive value of nine forage crops were compared at Qingyang Experimental Station of Lanzhou University. The crops examined were maize (*Zea mays*), oats (*Avena sativa*), soybean (*Glycine max*), pea (*Pisum sativum*), Proso millet (*Panicum miliaceum*), foxtail millet *(Setaria italica*), Sudan grass (*Sorghum sudanense)*, spring wheat (*Triticum aestivum*) and common vetch (*Vicia sativa*). All crops were sown on the 18 April 2009 and biomass was measured every 3 weeks until crop maturity or the first frost in October. Maize and Sudan grass produced the highest dry matter yields of 15 t DM ha^{-1} and 11t DM ha^{-1} after 15 weeks of growth, predominately during summer. Spring wheat produced the most biomass in spring with 2 t DM/ha at six weeks after emergence. Soybean and pea had a relatively high crude protein content and lower NDF (Neutral Detergent Fibre) content in early spring or mid summer than the other seven species. Maize and Sudan grass had the highest water-use efficiency over the whole growth season with 32.5 kg DM/ha.mm and 31.7 kg DM/ha.mm. This research demonstrated that cool-season forage crops (i.e. wheat, pea) could be particularly valuable in spring, however the most biomass could be produced from summer-growing species.

Key Words

Annual forage crops; nutritive value

Introduction

Crop-livestock systems of the western Loess plateau are often faced with a feed shortage in early spring and winter periods. This is a bottleneck that restricts the sustainable development of livestock production in the region. Thus, resolving the forage deficit in winter and spring to improve livestock production and nutrition requires supplementary feeding in those periods. In this study, it was hypothesized that spring-sown forage crops could be conserved as hay or silage for use during winter to early spring. To achieve such a goal, the conventional crop rotations could be modified by using existing spring sown grain crops as forages (e.g. maize, soybean) or partial replacement of these with alternative spring-sown forage crops. To test this hypothesis, an experiment was conducted to compare DM production, nutritive value and water use efficiency of nine annual forage crops.

Materials and Methods

Experimental site, design and treatments

The field experiment was conducted at Qingyang Experiment Station of Lanzhou University (35?41′N, 107?51′E), in the rainfed agricultural production zone of the western Loess Plateau. Average annual rainfall is 561mm, which is mostly distributed over the summer and autumn (June-Oct). The soil type is Heilu Loess soil, with low total nitrogen and low organic carbon.

Nine annual forage crops, maize (Z*ea mays)*, oat (*Avena sativa*), soybean (*Glycine max)*, pea (*Pisum sativum*), Proso millet (*Panicum milliaceum*), foxtail millet (*Setaria italica*), sudangrass (*Sorghum sudanense*), spring wheat (*Triticum aestivum*) and common vetch (*Vicia sativa*) were examined in this experiment. Plots were 5 ? 6 m arranged in a randomized complete block design with four replications.. All cultivars were sown on 18 April 2009.

Growth and forage quality measurements

Biomass of each annual forage crop was sampled every 3 weeks after emergence until maturity. For most species (those sown on 20 cm rows), plants were cut at ground level along 3 ? 0.5 m lengths of adjacent crop rows at 2 locations in each plot and bulked. For maize and Sudan grass (sown on 40 cm rows), only 2 ? 0.5 m rows were sampled. Biomass was then partitioned into leaf, stem and reproductive components, dried at 80?C for 48 hours, and the dry weight was recorded. Total N content (Kjeldahl method, and neutral and acid detergent fibre (NDF and ADF) (Goering and Van Soest 1970) were determined for each plant component at each time. Soil water content was measured coinciding with biomass cuts sampled to 2 m depth in following layers: 0-10, 10-20, 20-30, 30-60, 60-90, 90-120,120-150,150-200 cm.

Results

Biomass production

Spring wheat had the highest spring production, with greater than 2.5 t DM/ha at nine weeks after emergence. Other C3 species had produced < 1.5 t DM/ha at this time and had reached maturity by 12 weeks after emergence. Maize and Sudan grass produced the most total annual dry matter with peak growth occurring after the C3 species with the onset of warmer conditions between 9 and 15 weeks. Both millets and soybean also produced greater than 6 t DM/ha, although over a longer period than the cool-season species. The C4 species demonstrated higher WUE than the C3 species as expected (Table 1).

Table 1. Biomass production (kg DM/ha) and water-use-efficiency (kg DM/ha.mm) of 9 spring-sown forages in Gansu, northern China.

C_3/C_4	Species	3 wks	6 wks	9 wks	12 wks	15 wks	Final harvest	WUE
C_3	Spring wheat	188	1534	2670	-	-	1985	24.6
	Oat	69	714	1107	-	-	1382	17.3
	Vetch	17	313	1020	-	-	1113	13.5
	Pea	86	578	1120	-	-	1610	19.3
	Soybean	77	164	665	3110	3372	6660	19.5
C_4	Maize	39	642	3229	6541	13752	11697	32.5
	Sudan grass		290	1560	5250	8330	11010	31.2

Foxtail millet	21	912	1610	6640	--	8010	29.6
Proso millet	19	848	1890	5570	--	7610	31.2
LSD (*P=0.05*)	64	425	985	1696	3645	2845	0.69

Forage quality

Amongst the nine species, soybean and pea had consistently the highest crude protein content, followed by vetch (Table 2). In contrast, spring wheat had the lowest CP content early in its growth, though all grass species, except Proso millet, reached similar low levels at their final harvest (≈ 6%). Pea and vetch had the lowest NDF values; whereas the highest values were found for both millets. ADF followed the same trend as NDF; legumes had the lowest ADF compared with other species throughout the whole growth season. Ash did not show significant differences among nine species (data not shown).

Table 2. Crude protein, neutral detergent fibre content and acid detergent fibre content of 9 spring-sown forages through their growing season in Gansu, northern China.

Weeks after sowing	CP (%)				NDF (%)				ADF (%)			
Species	6 wk	9 wk	12 wk	Final harvest	6 wk	9 wk	12 wk	Final harvest	6 wk	9 wk	12 wk	Final harvest
Spring wheat	16.2	12.7		6.0	57.2	56.4		68.8	31.0	40.7		50.4
Oats	17.5	13.2	-	5.9	48.1	55.8		62.9	21.5	34.9		45.5
Vetch	23.4	16.0		13.7	39.2	38.1		42.4	29.0	32.1		35.2
Pea	21.5	21.6		17.1	32.5	34.3		47.8	29.9	36.7		45.5
Soybean		22.8	21.2	17.2	39.3	44.4	49.0	51.2	25.9	29.7	32.0	47.3
Maize	24.7	15.4	10.8	5.9	57.7	55.9	66.1	68.4	32.0	38.6	42.8	50.7
Sudan grass	24.0	16.0	12.0	5.7	65.6	55.7	62.7	67.1	31.2	36.3	38.4	45.6
Foxtail millet	23.3	15.6	11.8	6.2	62.6	62.1	72.5	75.9	26.2	39.3	42.8	53.1
Proso millet	24.8	15.1	12.8	8.3	60.0	62.7	73.3	75.2	28.4	30.9	40.2	42.8
LSD (P=0.05)	3.7	3.8	2.5	2.3	7.1	3.7	2.9	1.8	4.1	5.3	4.9	6.7

Discussion

Traditionally on the Loess Plateau, lucerne has been one of the most important forage sources, resulting in increased livestock production and improving rainfall use efficiency in a rotation with annual crops (Chen *et al.* 1992). Yet, annual forage crops might supplement other forage sources to further increase livestock production.

In this study we found that biomass production of spring wheat, a C_3 plant, was significantly higher than that for other species in early spring time, but that biomass production of C_4 plants (i.e. Sudan grass and maize) was higher during summer. Considering this, C_3 and C_4 plants could potentially be used to form a complementary system with balanced forage provision in all seasons. Oat performance was significantly lower than previous studies in the region, being only 66-80% of average district yields. This result may be due to the sowing time and the dry season, which featured less rainfall in early spring and summer during this experiment.

Crude protein content of forage is one of the most important criteria for forage quality evaluation (Caballero *et al.* 1995; Assefa and Ledin 2001). In all treatments, in spite of a comparatively low biomass yields, legume crops (i.e. soybean and pea) had higher CP content and provided forage of a higher quality for feeding livestock. Other important quality characteristics for forages are the concentrations of NDF and ADF (Caballero *et al.* 1995; Assefa and Ledin 2001). NDF and ADF respectively affect intake and digestibility of feeds for livestock. The actual values for ADF found in this study and the lack of significant differences in most cases are consistent with previous the studies of Caballero *et al.* (1995) and Velazquez-Beltran *et al.* (2002). That NDF also showed few significant differences is also consistent with previous studies (Lithourgidis *et al.* 2006). From this it can be concluded that a number of spring-sown forages can provide high quality forage and that these are similar in characteristics that affect feed intake and forage digestibility for livestock.

Conclusion

To maximize forage yield, spring wheat, maize and Sudan grass can be used in early spring to autumn. For forage quality, pea and soybean had high CP content and low ADF and NDF content throughout the whole growing season. C4 species were found to have significantly greater WUE than C3 species. The findings of this research indicate that the forage crops examined could be used to balance green forage supply at different periods of the year or to meet the specified nutritive demands of yield or quality.

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References

Armstrong D, Knee J, Doyle P, Pritchard K, Gyles O (1998). A survey of water-use efficiency on irrigated dairy farms in northern Victoria and southern New South Wales. Natural Resources and Environment, Institute of Sustainable Irrigated Agriculture, Kyabram Dairy Centre, Kyabram.

Lithourgidis AS and Vasilakoglou IB (2006). Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crops Research. 99, 106-113

Assefa G and Ledin, I (2001). Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. Anim.Feed Science and Technoogy. 92, 95–111.

Caballero R, Goicoechea EL and Hernaiz PJ (1995). Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of common vetch. Field Crops Research 41, 135–140.

Chapman DF, Tharmaraj, J and Nie ZN (2008). Milk production potential of different pasture types in a temperate southern Australia environment. Grass and Forage Science 62, in press.

Chen W, Liu ZH, Yang MY, Eagleton Ge, Lisele RL and Mitchelhill BK (1992) The role of lucerne (*Medicago sativa* L.) in developing the agricultural systems of eastern Gansu, China, Proceedings of the 6th Australia Agronomy Conference Armidale, NSW, Australia, pp. 422–424.

Garcia SC, Fulkerson WJ and Brookes SU (2008). Dry matter production, nutritive value and efficiency of nutrient utilization of a complementary forage ration compared to a grass pasture system. Grass and Forage Science63, 284-300

Goering HK and Van Soest PJ (1970) Forage fiber analyses (apparatus, reagents, procedures and some applications). Agricultural Handbook No. 379 ARS, USDA, Washington, D.C.

Lithourgidis AS, Vasilakoglou IB, Dhima KV, Dordas CA and Yiakoulaki MD (2006) Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crops Research 99, 106-113.

Zhu Shuguo and Liu Jinghui. (2008). Accumulation and Distribution of Silage Maize Crude Ash and Nitrogen Free Extract in Different Harvest Periods. Maize Science16, 110-114

Vel?zquez-Beltr?n LG, Felipe-P?rez YE and Arriaga-Jord?n CM (2002 Common vetch (*Vicia sativa*) for improving the nutrition of working equids in *Campesino* systems on hill slopes in central Mexico. Tropical Animal Health and Production 34, 169-179.