Forage quality of sorghum, sudan-grass sorghum x sudan-grass and pearl millet cultivars in Manawatu

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Abstract

Sorghum, sudan-grass and pearl millet are summer forages typically fed to lactating cows and beef animals as a supplementary feed. Forage quality has a major influence on the intake and performance of animals in dairy and beef systems. A trial planted at Massey University, Palmerston North on 8 December 2009 compared agronomic traits, crop morphology and forage quality of four sorghum x sudan-grass hybrids (Pac 8421, Pac 8423, Pacific BMR and Bettagraze), two sudan-grass (Superdan 2 and Sprint), one sweet sorghum (Sugargraze) and one pearl millet (Nutrifeed) cultivar. There were significant cultivar differences in leaf:stem ratio, tiller density and crop height at the time of yield measurement. Sugargraze (153.9 cm) was taller than all other cultivars while Nutrifeed (76.9 cm) was shorter than all other cultivars apart from Pacific BMR (89.1 cm). Metabolisable energy (P=0.0001) ranged from 10.1 to 11.0 MJ kg^{-1} DM with Pacific BMR having higher levels than other cultivars apart from Nutrifeed and Pac 8421. Sugargraze had the lowest metabolisable energy. Sugargraze also had significantly (P<0.0001) lower crude protein content (10.3%) than all other cultivars; highest crude protein occurred in Nutrifeed (18.0%), Pacific BMR (16.8%) and Bettagraze (16.1%). Both metabolisable energy and crude protein were strongly, negatively associated with plant height.

Additional keywords: metabolisable energy, acid detergent fibre, neutral detergent fibre, protein, starch, soluble sugars, plant height

Introduction

Sorghum (*Sorghum bicolour* (L.) Moench), sudan-grass (*Sorghum sudanense* (Piper) Stapf.) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) are warm-zone cereals grown as forage for livestock in regions where high temperature and low rainfall during late summer and early autumn results in feed deficits on pastoral farms. Sorghum can be classified into 3 groups; forage sorghum, sudan-grass and sorghum x sudan-grass hybrids (Douglas, 1980). Forage sorghums are mainly ensiled or made into hay while sudan-grass and sorghum x sudan-grass hybrids are primarily grazed. Maize is the most important warm season forage crop in New Zealand, and generally produces higher yields than the forage sorghums, but is not suitable for grazing (Douglas, 1980).

Some research was carried out on forage sorghum, sudan-grass and sorghum x sudan-grass hybrids during the 1970's (Cottier, 1973; Gerlach and Cottier, 1974) in New Zealand, but there has been little recent research on these crops. This trial was undertaken to evaluate the performance, in particular the forage quality, of a range of currently available cultivars and cultivars being assessed for release in New Zealand.

Materials and Methods

The trial work was conducted on a fertile site (Table 1) on the Pasture and Crop Research Unit, Massey University, Palmerston North (40°22’56”S; 175°36’26”E). Full details of the trial can be found in Silungwe *et al.* (2010). Briefly, four sorghum x sudan-grass hybrids (Pac 8421, Pac 8423 and Pacific BMR, all brown midrib (BMR) hybrids and Bettagraze), two sudan-grass (Sprint and Superdan 2), one sweet sorghum (Sugargraze) and one pearl millet (Nutrifeed) cultivar were evaluated. Treatments were arranged in a completely randomised block design with 4 replicates. The trial was planted on 8 December 2009. Meteorological data was obtained from the AgResearch Grasslands, Palmerston North weather station. Mean air temperature for the November 2009 to March 2010 period was generally lower than the long term mean, however February was warmer than normal (Table 2).

Table 1: Soil nutrient analysis.

Nutrient	mg kg^{-1} of soil
Nitrogen	76.81
Phosphorus	36.0
Potassium	86.02
Calcium	1380
Magnesium	146.41
Sodium	27.6

Table 2: Mean air temperatures (°C) for the 2009-2010 season compared with the long term mean (NZMS, 1983), AgResearch Grasslands, Palmerston North.

	Month				
	November	December	January	February	March
2009-2010 mean	13.0	15.4	17.3	18.7	15.9
Long term mean	14.2	16.1	17.3	17.6	16.4

Plant height (PH), tiller density, dry matter (DM) yield and forage quality were determined. Plant height was measured weekly as the height between the horizontal curve of the tallest leaf and the soil surface. Harvest occurred at approximately 100cm plant height, 58 days after planting for all cultivars apart from Sugargraze which was harvested after 78 days (23 February 2010). After weighing, ten tillers were randomly sampled from harvested material from each plot to determine the %DM and dissected into leaf and stem components to allow calculation of the yield of each component and the leaf: stem ratio. All samples were dried in a forced air oven at 70°C for 72 hours.

After determination of DM the leaf and stem components were ground using a cyclone mill (1.0 mm screen) and thoroughly mixed (Marsalis *et al*., 2010): 27 g of each sample was sent to the Animal Nutrition Laboratory, Institute of Food Nutrition and Human Health, Massey University, for quality analysis. Crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), metabolisable energy (ME) and soluble sugars and starch (SSS) were measured using near infrared reflectance (NIR) spectrometry (Collins and Fritz, 2003; Ketterings *et al*., 2005; Kilcer *et al*., 2005; Marsalis *et al*., 2010). Metabolisable energy is used as the standard for expressing feeding value in New Zealand (Waghorn *et al*., 2007).

The NIR was calibrated by the manufacturer for each component by scanning finely ground pasture samples in a range from 400 nm to 2500 nm wavelength. When calibrating, pasture samples were analysed using wet chemistry methods. These included the Association of Official Analytical Chemists test for crude protein (AOAC 968.06) using a LECO FP-2000 combustion analyser (LECO Corporation, St Joseph, Michigan, USA), an enzymatic gravimetric method using the Tecator fibertec system (Foss Tecator Sweden) for ADF and NDF, sulphuric acid phenol and AOAC 996.11 and amylase method for soluble sugar and starch by the methods of Van Soest *et al*. (1991). Metabolisable energy (ME) was calculated from predicted dry matter digestibility values (Clarke *et al*., 1982). The resulting NIR calibrations against the wet chemistry results for each component typically had a correlation of 0.90.

The Proc GLM procedure of SAS was used to analyse treatments effects. Least significant differences were used to separate means at P=0.05. Proc CORR was used to explore the association among forage quality traits and plant height and the leaf:stem ratio.

Results

Significant cultivar yield differences were measured in this study. Bettagraze and Pac 8421 yielded significantly ($P<0.05$) more than all other cultivars. Full details of cultivar effects on yield have been reported previously (Silungwe *et al*., 2010). There were significant cultivar differences in crop structure (Table 3). Leaf:stem ratio's ranged from 1.6 to 2.1; Nutrifeed (1.7) and Sugargraze (1.6) had lower ratio's than all other cultivars (2.0 to 2.1). There were also significant differences in crop height at the time of yield measurement. Sugargraze (153.9 cm) was taller than all other cultivars while Nutrifeed (76.9 cm) was shorter than all other cultivars apart from Pac BMR (89.1 cm). Sprint (412 tillers m^{-2}) and Superdan 2 (392 tillers m^{-2}), both sudan-grass cultivars, had significantly higher tiller densities than all other cultivars.

Table 3: Height (cm), leaf:stem ratio and tiller density (tillers m^{-2}) for different sorghum, sudan-grass, sorghum x sudan-grass and pearl millet cultivars planted on the 8 December 2009

Cultivar	Height	Leaf:Stem	Tiller density
Bettagraze	118.8	2.0	265.0
Nutrifeed	76.9	1.7	342.0
Pac 8421	106.0	2.0	267.0
Pac 8423	119.6	2.0	261.0
Pacific BMR	89.1	2.0	208.0
Sugargraze	153.9	1.6	228.0
Sprint	122.7	2.1	412.0
Superdan 2	109.6	2.1	392.0
Significance	0.0001	0.0001	0.0001
$LSD_{(0.05)}$	16.2	0.1	60.0

Forage quality

Significant cultivar effects were observed in all forage quality attributes assessed (Table 4). Metabolisable energy (P=0.0001) ranged from 10.1 to 11.0 MJ kg^{-1} DM. Pacific BMR had the highest ME, but did not differ from Nutrifeed and Pac 8421. Sugargraze had lower ME content than all other cultivars while ME content in the remaining cultivars was similar. Sugargraze also had significantly (P<0.0001) lower CP (10.3%) than all other cultivars. The highest CP was measured in a group of cultivars including Nutrifeed (18.0%), Pacific BMR (16.8%) and Bettagraze (16.1%).

There were significant cultivar differences in fibre, both ADF (P=0.0009) and NDF (P=0.003). The lowest ADF and NDF content occurred in Pacific BMR. The differences in ADF and NDF among the remaining cultivars were generally small and not significant. Sugargraze, Sprint, Pac 8423 and Bettagraze had the highest NDF concentrations.

There were relatively large differences in SSS content. Highest concentrations were measured in Sugargraze (13.9%) followed by Pacific BMR (10.3). A group of cultivars including Sprint, Superdan 2, Pac 8423, Pac 8421 and Bettagraze were intermediate while Nutrifeed had significantly lower SSS than all other cultivars.

Table 4: Whole plant metabolisable energy (ME), crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and soluble sugars and starch (SSS) of different sorghum, sudan-grass, sorghum x sudan-grass and pearl millet cultivars.

	ME (MJ kg^{-1} DM)	CP (%)	ADF (%)	NDF (%)	SSS (%)
Bettagraze	10.3	16.1	35.5	62.8	6.2
Nutrifeed	10.8	18.0	33.9	61.1	1.2
Pac 8421	10.8	16.0	34.2	60.6	7.9
Pac 8423	10.3	14.2	36.5	63.1	7.6
Pacific BMR	11.0	16.8	32.9	57.2	10.3
Sugargraze	10.1	10.3	36.2	65.2	13.9
Sprint	10.4	14.7	36.3	62.0	8.5
Superdan 2	10.5	15.0	35.2	59.9	7.2
Significance	0.0001	0.0001	0.0009	0.003	0.0001
$LSD_{(0.05)}$	0.3	2.0	1.6	3.4	1.4

Relationships among forage attributes

Both ME (Figure 1) and CP (Figure 2) content declined linearly as crop height increased however, the relationship between crop height and CP (R^2=0.71) was slightly stronger than that between crop height and ME (R^2=0.60). Consequently, the relationship between ME and CP was positive and moderately strong; R^2=0.59 (Figure 3). Correlation analysis did not reveal significant associations among the remaining forage traits.

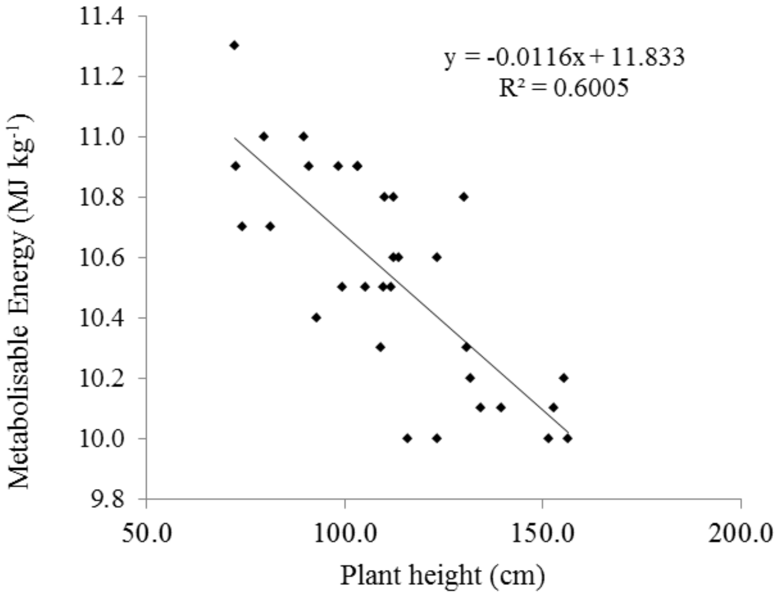

Figure 1: Relationship between plant height and forage metabolisable energy for sorghum, sudan-grass, sorghum x sudan-grass and pearl millet cultivars.

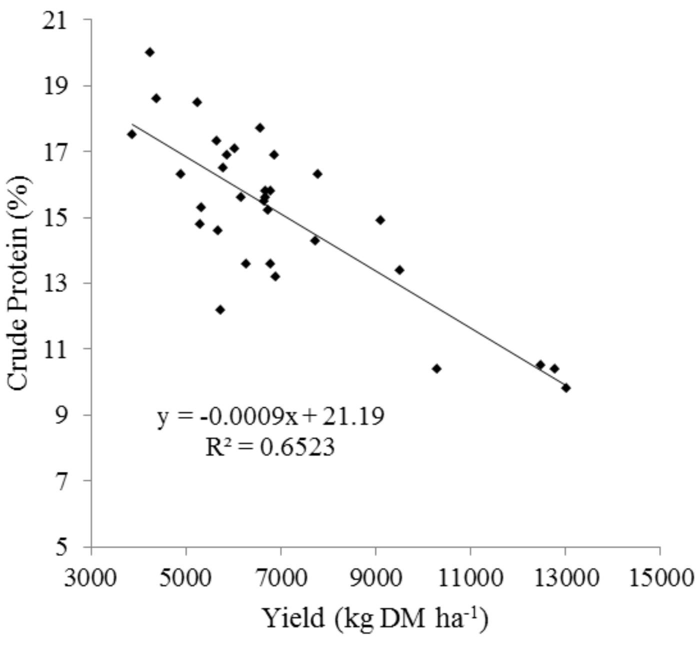

Figure 2: Relationship between plant height and forage crude protein content for sorghum, sudan-grass, sorghum x sudan-grass and pearl millet cultivars.

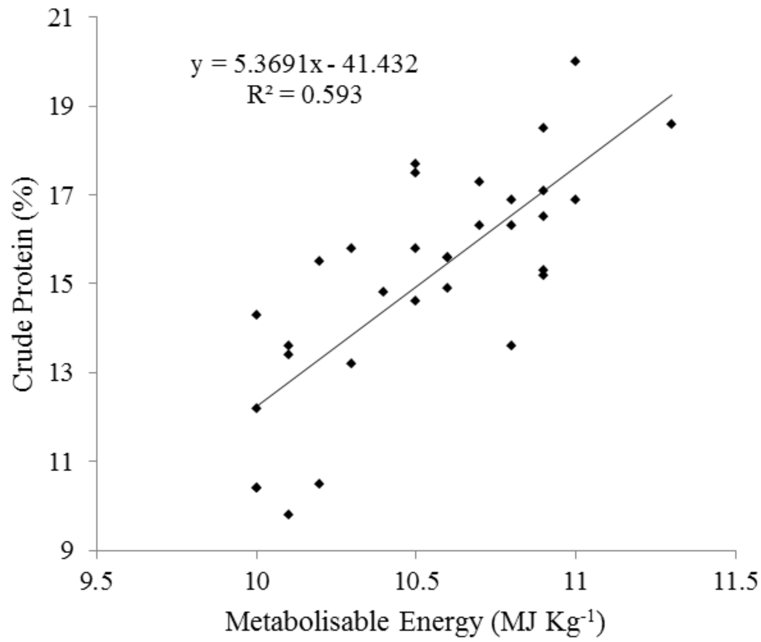

Figure 3: Relationship between forage metabolisable energy and crude protein content for sorghum, sudan-grass, sorghum x sudan-grass and pearl millet cultivars.

Discussion

Metabolisable energy

In general, the metabolisable energy (ME) content of the different cultivars (10.1 to 11.0 MJ kg^{-1} DM) in this study, was higher than those reported by Miller and Stroup (2004) (8.5 to 9.3 MJ kg^{-1} DM) and Moss (2009) (8 to 9.5 MJ kg^{-1} DM). This is probably because of lower fibre content in the current study. For example, the mean ADF (35.1%) and NDF (61.5 %) content were less than the means for ADF (40%) and NDF (68%) reported by Moss (2009). The low fibre contents in this study may be a result of the relatively low temperatures experienced during the trial; temperatures marginal for sorghum growth can reduce fibre synthesis (Ford *et al.*, 1979; Peacock, 1982; Wilson *et al.*, 1991).

The ME values achieved in this study are similar to those reported for maize silage in New Zealand; 10.3 to 12.4 MJ kg^{-1} DM (Millner *et al.*, 2005; de Ruiter *et al.*, 2007) but lower than the ME of whole turnips (11.8 to 12.5 MJ kg^{-1} DM) reported by de Ruiter *et al.* (2007) and (11 to 13 MJ kg^{-1} DM) by Clark *et al*. (1996), also utilised as a summer supplementary forage for lactating dairy cows. However, the ME levels obtained here are greater than those (>10 MJ kg^{-1} DM) suggested by Litherland and Lambert (2007) to be approriate for silage used during summer feed deficits in dairy systems. They are also greater than the ME levels needed for maintenance feeding (7 to 9 MJ kg^{-1} DM) and moderate growth (10 MJ kg^{-1} DM) in beef animals (Suyama *et al*., 2007).

Pacific BMR and Pac 8421 had the highest ME contents, which is attributable to the presence of the BMR gene which reduces fibre content (Casler *et al.*, 2003). One of the non BMR cultivars (Nutrifeed) also had high ME. This may be because it is a leafy cultivar which results in increased digestibility (Chu and Tillman, 1976; Ball, 1998). However Pac 8423 had low ME compared to the other BMR cultivars, a result of high ADF and NDF fibre contents. Plant height (119.6cm) of this cultivar at the time of harvest was greater than that of Pacific BMR (89.1 cm) and Pac 8421 (106.0 cm). There was a negative relationship between height and ME content in this study (Figure 1); increased height results in increased fibre content in sorghum (Buxton and Fales, 1994).

Crude protein

The mean CP content (15.1%) was similar to the CP content (14%) for sorghum reported in New Zealand (Douglas, 1980) and Australia (Moss, 2009). The CP percentages of all cultivars assessed in this study were higher than that for maize silage CP (5.4 to 8.2%) reported by de Ruiter *et al*. (2007) and Millner *et al*. (2005) (6.6 to 7.3%) in New Zealand. In most cultivars CP was within the CP content range (14.2% to 18.7%) reported for summer turnips in New Zealand (de Ruiter *et al*., 2007) and Australia (Jacob *et al*., 2004). The high CP levels achieved may be attributable to high N availability (Table 1) at the trial site (Moss, 2009).

The highest CP occurred in Nutrifeed pearl millet (18.0%), despite a low leaf:stem ratio, usually associated with low CP (Wall and Ross, 1970; Ball, 1998). This is probably a result of low stature, and as a consequence, yields (Silungwe *et al*., 2010) in this cultivar. Conversely Sugargraze (sweet sorghum) had a low CP content, the result of later harvesting, greater height and yield and consequently, dilution of CP (Snyman and Joubert, 1996). Some researchers have found that BMR cultivars have a higher CP content than non BMR cultivars (Reich, 2007) however, in this study CP content of the BMR cultivars was variable, reflecting their yield (Silungwe *et al*., 2010).

Soluble sugars and starch

Large differences in soluble sugars and starch were observed among the cultivars being evaluated. Levels tended to be highest in the tall cultivars at time of harvest and least in short cultivars at time of harvest. Leaf number increases with plant height and results in increased leaf area; leaf area has been positively associated with high SSS levels in sorghum (Worker and Marble, 1968).

Relationships among forage quality traits

The ME of these crops decreased with increasing plant height (Figure 1) probably because as plant height increases highly lignified support tissue, such as sclerenchyma, are produced to maintain crop stability. High lignin content reduces forage digestibility (Akin, 1989). The reduction in CP content with increased plant height is a reflection of the protein dilution effect; the accumulation of DM occurs at a greater rate than the accumulation of protein (Ayub, 2009; Van Soest, 1994). Increased plant height may also reduce CP concentrations because of decreased leaf:stem ratio's associated with increased height (Buxton and Casler 1993; Kilcer *et al*., 2005). Leaf:stem ratio appears to have had minimal effect on CP in this study; ratios were lowest in Sugargraze and Nutrifeed, which were the tallest and shortest cultivars at harvest, respectively.

Conclusions

Forage quality among the cultivars evaluated was variable; crude protein ranged from deficient to adequate for lactating animals (10.3 to 18.0%) but metabolisable energy levels were moderately high (10.1 to 11.0 MJ kg DM^{-1}) in all cultivars. There was a strong negative relationship between plant height (yield) and crude protein and metabolisable energy content, while crude protein and metabolisable energy were positively correlated. Among the BMR cultivars, Pac 8421 appeared to be a better prospect than Pacific BMR having similar forage quality but higher yield.

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