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Variability in Stover Quality Traits in Commercial Hybrids of Pearl Millet *(Pennisetum glaucum (L.) R. Br.)* and Grain - Stover Trait Relationships

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ABSTRACT

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Pearl millet stover is an important cattle feed particularly in arid areas and nutritional quality traits of the stover become more and more important. Eight commercial and two experimental hybrids of pearl millet were evaluated for stover fodder quality traits and their potential trade-off with stover and grain yield. The stover quality traits analyzed were nitrogen, *in vitro* digestibility and metabolisable energy content. Highly significant ($P<0.01$) variations were observed for grain yields (2860 to 4220 kg/ha), stover yields (range 3760 to 4930 kg/ha), stover nitrogen (0.62 to 1.10%), stover *in vitro* digestibility (37.6 to 46.7%) and stover metabolisable energy (5.26 to 6.88 MJ/kg). Stover nitrogen content was negatively associated with grain and stover yield but no such trade-offs were observed between stover *in vitro* digestibility and metabolisable energy contents on one hand and grain and stover yield on the other. Hybrid GK 1044 had the lowest stover nitrogen content (0.62%) and highest stover digestibility (46.7%) and metabolisable energy (6.88 MJ/kg), while MLBH 267 with the highest stover nitrogen (1.10%) and the lowest stover digestibility (37.6%) and metabolisable energy (5.26 MJ/kg). These two contrasting hybrids were re-planted on large plots in the second year and their stover tested *in vivo* with sheep as sole feed. Digestible organic matter intake was significantly higher in GK 1044 than in MLBH 267 (13.5 versus 12.5 gram per kg live weight) and nitrogen balance tended ($P<0.10$) to be more favourable in GK 1044 than in MLBH 267 (-0.008 versus -0.10 gram per kg live weight. These results show that among commercial high-yielding pearl millet hybrids, some can be found with high grain and stover yield, high stover digestibility and metabolisable energy. The observations from the feeding trial suggest that stover *in vitro* digestibility and metabolisable energy are more important than stover nitrogen content in determining stover quality.

Key words: Pearl Millet-Stover, Grain-Stover, Trait Relationship, Fodder Quality.

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INTRODUCTION

Pearl millet stover is an important fodder resource for ruminants in smallholder crop-livestock systems in most of the arid and semi-arid tropical zones of the Indian subcontinent (Kelley and Rao, 1996; Kelley *et al.* 1996). While key criteria for stover fodder quality such as protein content, digestibility and metabolisable energy content are on the lower side when compared with leguminous crop residues or planted fodder, significant variations in stover quality have been found in pearl millet (Bidinger and Blümmel, 2007; Blümmel *et al.* 2007). Cultivars–dependent variations in stover fodder quality can be utilized by essentially two approaches: a) by detecting and exploiting variation in stover fodder traits that exist without having been specifically bred or selected for; and b) by targeted genetic enhancement for higher stover yield and quality. The first approach can target new cultivar release programs by including stover traits as release criteria, which is promising and with considerable impact potential (see companion papers in this special issues) but the approach requires considerable, while perfectly feasible, infrastructure for phenotyping. Very little investment and infrastructure is required when this approach is applied to released and popular cultivars which are often few in numbers. This paper reports on variability for Stover quality traits in commercial cultivars of pearl millet and examines the relationships of these traits with grain and stover yields.

MATERIALS AND METHODS

Experimental materials and field trials

Eight commercial hybrids (GK 1044, MLBH 308, Rani, ICM 9444, JKBH 676, PAC 931, MLBH 267, JKBH 26) and two experimental hybrids (ICMH 01122 and ICMH 01144) were evaluated in the rainy season of 2007 at the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) at Patancheru, Andhra Pradesh, India. The experimental layout was a replicated alpha-design with 4-row plots of 4-m length and 0.6 m spacing between the rows and evaluated in a RCB design with three replications. All agronomic and physiological observations were obtained from the central two rows (4.8 m^2). From analysis of the 2007 grain and stover yields and stover fodder quality traits, two contrasting hybrids (GK 1044 with superior stover quality traits and MLBH 267 with inferior stover quality traits), were replanted in 2008 on large plots to obtain some estimates of year to year repeatability of food-feed traits, and more importantly, to test their stover in feeding trials with sheep. Grain and stover yields and days to flowering were recorded using standard agronomic practices.

Stover quality analysis

Stover nitrogen content, *in vitro* digestibility and *in vitro* metabolisable energy were estimated using a combination of conventional chemical and *in vitro* laboratory analysis and Near Infrared Reflectance Spectroscopy (NIRS) as described by Bidinger and Blümmel, (2007) and Blümmel *et al.* (2007). The stover from the two cultivars grown on the large plots in the second year were harvested after grain maturity, chopped and artificially dried in drying bins. It was then fed *ad libitum* (allowing for about 15%

of refusals) to a group of 12 Deccan sheep with an average live weight of about 20 kg housed in metabolic cages. The sheep were adjusted to stover for two weeks followed by a one week faecal and urine collection period.

Statistical analysis

The analysis of variance for the cultivar effects was done using SAS PROC GLM (SAS, 1988). Linear relationships between grain and stover traits were calculated using GraphPad Prism (1994). For relationships with probability values of < 0.1, correlation coefficients were reported in the figures while for probability values > 0.1 only P values were reported.

RESULTS

Differences in grain and stover yield and stover fodder quality traits among pearl millet hybrids

There were highly significant differences among the hybrids for grain and stover yields (Table 1). GK 1044 had the highest grain yield (4220 kg/ha), out yielding the lowest yielder by more than 1.3 tons/ha, while MLBH 308 had the highest Stover yield (4930 kg/ha), out yielding the lowest stover yielder by more than 1.1 tons/ha. Based on both grain and Stover yield, these two hybrids were the best in the trial, with no significant difference between them either for the Stover or grain yield. Similarly, highly significant differences among the hybrids were observed for stover nitrogen content, *in*

Table 1. Grain and stover yields and stover nitrogen content, *in vitro* digestibility and metabolisable energy content in ten pearl millet hybrids

Cultivar	Grain Kg / ha	Stover Kg / ha	Nitrogen %	Digestibility %	Metabolisable energy MJ/kg
GK 1044	4 216	4 771	0.62	46.7	6.88
MLBH 308	4 021	4 933	0.76	39.8	5.67
Rani	3 863	4 901	0.67	45.8	6.72
ICM 9444	3 819	4 172	0.79	37.9	5.40
JKBH 676	3 669	4 901	0.63	38.9	5.59
ICMH 01122	3 252	4 338	0.84	39.2	5.59
PAC 931	3 141	4 242	0.73	39.5	5.62
MLBH 267	3 041	3 758	1.10	37.6	5.26
ICMH 01144	2 891	3 970	0.99	39.4	5.57
JKBH 26	2 855	4 133	0.67	41.4	6.02
Range	1361	1175	0.39	9.1	1.62
LSD (5%)	241	413	0.02	1.2	0.20
P > F	<0.0001	<0.0001	0.0001	0.0001	0.0001

vitro digestibility and metabolisable energy. Stover nitrogen content varied from 0.62% in GK 1044 to 1.10% in MLBH 267, *in vitro* digestibility varied from 46.7% in GK 1044 to 37.9% in MLBH 267. Ranking by metabolisable energy (ME) content was similar to that by *in vitro* digestibility and highest and lowest ME were observed in GK 1044 and MLBH 267, respectively.

Relationships between stover fodder quality traits and grain and stover yield

The relationships between stover nitrogen contents, *in vitro* digestibilities and metabolisable energy contents and grain yields are presented in Figure 1a-c. Stover nitrogen content tended to be inversely related to grain yield (r = -0.56, P = 0.10). In contrast *in vitro* digestibility and metabolisable energy tended to be positively associated with grain yield (P<0.15).

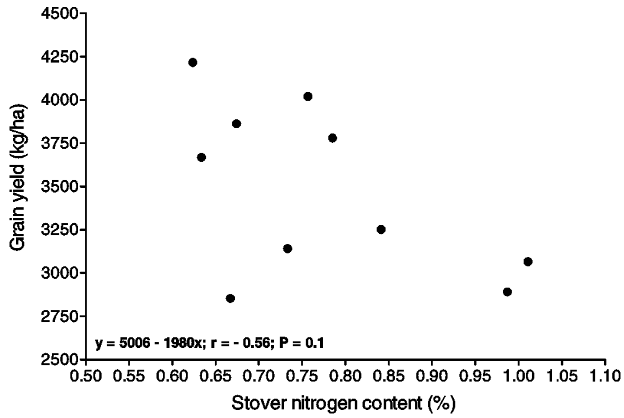

Fig. 1a. Relationship between stover nitrogen content and grain yield in ten pearl millet hybrids

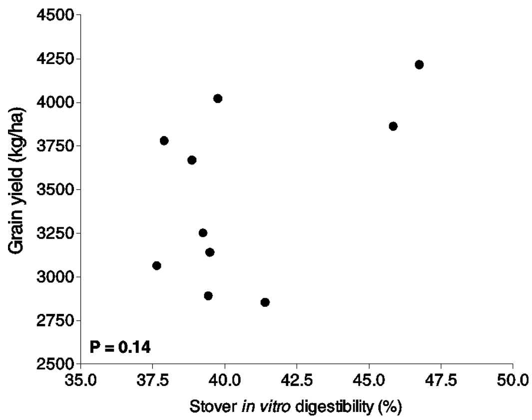

Fig. 1b. Relationship between stover *in vitro* digestibility and grain yield in ten pearl millet hybrids

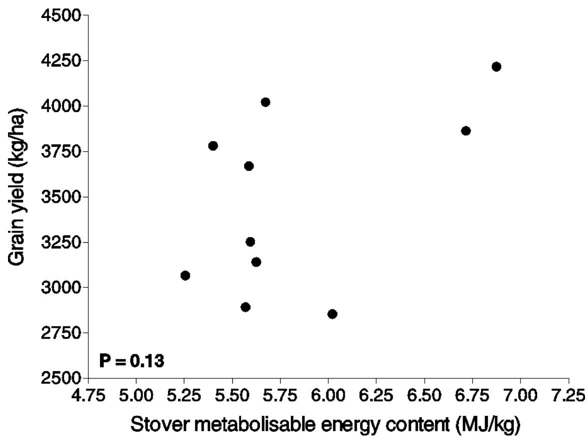

Fig. 1c. Relationship between stover metabolisable energy content and grain yield in ten pearl millet hybrids

Similar but somewhat stronger relationships were observed between stover fodder traits and stover yield (Figures 2a-c). Stover nitrogen content was significantly inversely related to stover yield (r = -0.75, P=0.01). Positive associations were observed between stover yield and *in vitro* digestibility (r=0.54, P=0.11) and metabolisable energy (r=0.57, P = 0.09).Days to flowering (Figure 3) tended to be positively associated (P=0.09) with grain yield while this relationship was weaker with stover yield (P=0.23). Days to flowering tended to be negatively associated (P=0.1) with stover nitrogen content but no relationships were observed with stover *in vitro* digestibility (P=0.52) and metabolisable energy (P=0.49).

Superior food-feed traits in cultivar GK 1044 were also observed in 2008 (Table 2) where the cultivar outperformed MLBH 267 in grain and stover yield and in stover *in vitro* digestibility and metabolisable energy.

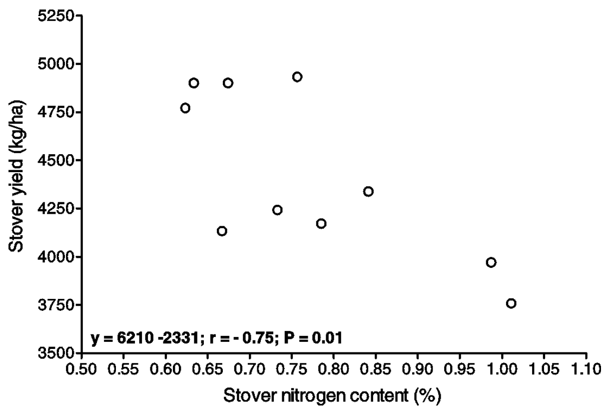

Fig. 2a. Relationship between stover nitrogen content and stover yield in ten pearl millet hybrids

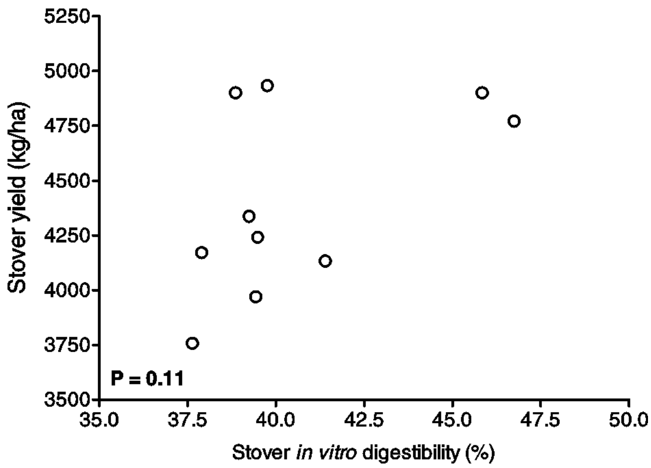

Fig. 2b. Relationship between stover *in vitro* digestibility and stover yield in ten pearl millet hybrids

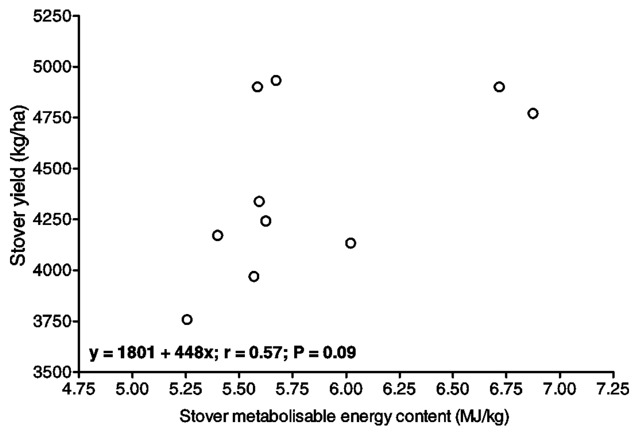

Fig. 2c. Relationship between stover metabolisable energy content and stover yield in ten pearl millet hybrids

Higher stover fodder quality in GK 1044 were confirmed in the feeding trial with sheep where GK 1044 had significantly higher *in vitro* digestibility and digestible organic matter intake and also tended (P = 0.01) to support a more favourable nitrogen balance compared to MLBH 267 (Table 3)

DISCUSSION

Variations in food-feed traits and possible trade-offs

Food-feed crop research through multidimensional crop improvement responds to farmers needs for food and fodder (Reddy *et al*. 1995; Kelley *et al*., 1996) While the relative importance of grain to stover traits will vary with regions and farming system,

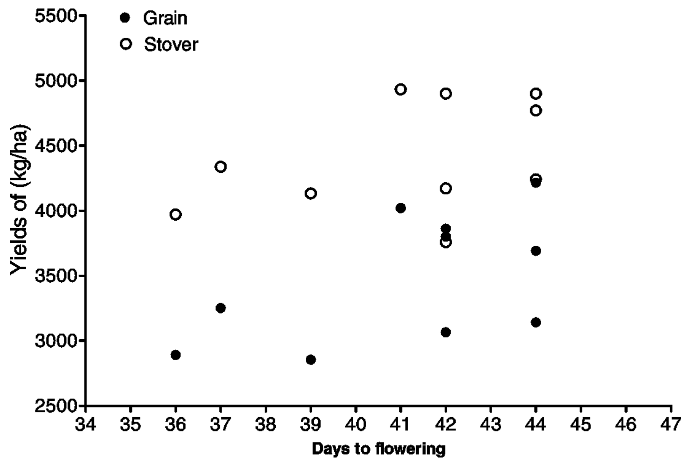

Fig. 3. Relationship between days to flowering and grain and stover yields in ten pearl millet hybrids

Table 2. Grain and stover yields and quality traits in the two contrasting pearl millet cultivars.

Cultivar	Grain (kg/ha)	Stover (kg/ha)	Nitrogen (%)	Digestibility (%)	Met. Energy MJ/kg
GK 1044	3 890	5 790	0.64	47.7	7.08
MLBH 267	2 930	4 410	0.84	43.8	6.28

Table 3. Organic matter (OM) digestibility, OM intake, digestible OM intake and nitrogen balance in stover of two contrasting pearl millet cultivars when fed *ad libitum* to sheep.

Cultivar	OMD (%)	OMI (g/kg LW)	DOMI (g/kg LW)	N balance (g/kg LW)
GK 1044	59.8[a]	22.5	13.5[a]	-0.009
MLBH 267	55.5[b]	22.5	12.5[b]	-0.05

Different superscripts denote significant differences ($P<0.05$).

stover traits are becoming more important as reflected in the increasing price of stover relative to grain price, which are now approaching 1:2 (Kelley *et al.*, 1996; Blümmel and Rao, 2006). However, as the findings of the present work show crucial pearl millets stover traits could be improved without detriment to grain yield (see Figures 1b/c). Stover nitrogen content, *in vitro* digestibility and metabolisable energy were chosen as stover quality traits in the present work. Low nitrogen (N) content is often considered to be one of the most limiting factors in the utilization of cereal crop residues as livestock fodder, as N contents below 1.0–1.2% in fodder dry matter is thought to depress voluntary feed intake because of lack of N for rumen microbes (Van Soest, 1994). Voluntary feed intake in turn is a crucial quality trait in cereal crop residues whenever farmers have sufficient residues to feed their animals according to appetite. *In vitro* digestibility gives an estimate about the proportion of the fodder availability in the animal while metabolisable energy determination enable reliable estimations of the fodders potential to support maintenance requirement and milk and meat production (McDonald *et al.* 1988). The present work showed significant variations in all three stover quality traits among the 10 pearl millet hybrids but high stover nitrogen content will come with a penalty for grain and stover yields (Figures 1a/2a) confirming earlier findings of Bidinger and Blümmel (2007) and Blümmel *et al.* (2007). However, there is considerable evidence that in pearl millet stover digestibility is a more important fodder quality trait than stover nitrogen content. Thus, Ravi *et al.* (2009) investigated the relationship between the *in vivo* organic matter digestibility (OMD), organic matter intake (OMI), digestible organic matter intake (DOMI) and nitrogen balances (N-Bal.) of 40 pearl millet stover fed to sheep *ad libitum* as sole feed. *In vitro* digestibility and ME were consistently closely related to the *in vivo* measurement than stover nitrogen content accounting for example for 44% of the variation in OMI while stover nitrogen content explained only 37% of the variations in OMI. The findings of Ravi et al (2009) are corroborated by results from the present work where GK 1044 had higher DOMI and even more favourable nitrogen balance than MLBH 267 despites the latter higher stover nitrogen content.

Potential impact of variations in food-feed traits in pearl millet

Bidinger and Blümmel (2007) and Blümmel *et al.* (2007) compared a wide range of pearl millet landraces, open pollinated varieties and hybrids for variations in food-feed traits over two years and different management systems and reported across-treatments stover *in vitro* digestibilities in the range of 38.9 to 42.7% i.e. the exploitable cultivar variation was 3.8 percentage units. In the present work the two years average in *in vitro* digestibility of stover of GK 1044 was 47.2% (range 46.7 to 47.7%) which is higher than any of the observations reported by Bidinger and Blümmel (2007) and Blümmel *et al.* (2007). Digestibility was the key variable in ex-ante impact assessments of the genetic enhancement of sorghum and pearl millet stover as livestock fodder (Kristjanson and Zerbini, 1999). These authors calculated that a one-percentage unit increase in digestibility would result in increases in milk, meat and draught power outputs ranging from 6 to 8 percent. In sorghum stover a cultivar-dependent difference of 5 percentage units (47 to 52%) in *in vitro* digestibility equated to about a 25% higher price (4 Indian Rupees per kg of dry stover compared to 3 Rupees) in a yearlong survey of stover traders in Hyderabad (Blümmel and Rao, 2006). From the findings of the present work, it appears that pearl millet stover *in vitro* digestibility can reach higher levels than previously thought and, in fact, can match that of some of the sorghum stover commercially successfully traded. Since in the case of GK 1044 this high stover digestibility came with no penalty on grain and stover yield, whole plant utilization and income for farmers could substantially benefit from higher stover digestibility and metabolisable energy of this hybrid.

However, while GK 1044 did well in both years investigated in Patancheru in AP, farmersin Northern India complained about susceptibility to stover leaf diseases (probably blast)and poor stover storage properties when asked about their perception of stover traits of GK1044 when contacted by the seed producer in 2009. Therefore cultivars should be tested inenvironments.

CONCLUSION

Considerable variation in stover fodder quality traits can be found in commercial pearl millet hybrids that, apart from high grain and stover yields, may be high in stover digestibility and metabolisable energy. Since pearl millet is mainly grown in areas with low rain fall and low crop yields where livestock play a crucial role superior dual-purpose pearl millet cultivars can have a significant impact on livelihoods.

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