Utilization

Genotype × Environment Interactions in Food-feed Traits in Pearl Millet Cultivars

CT Hash[1], **M Blümmel**[2]* and **FR Bidinger**[1]
[1. International Crops Research Institue for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India;
2. International Livestock Research Institute (ILRI), c/o ICRISAT, Patancheru 502 324, Andhra Pradesh, India]
*Corresponding author: m.blummel@cgiar.org

Introduction

Pearl millet [Pennisetum glaucum (L.) R. Br.] stover provides a crucial fodder resource for ruminant animals in small-holder crop-livestock systems in most of the arid and semi-arid zones of the Indian subcontinent (Kelley and Rao 1996). This is especially the case where (1) the dry season is too long (≥6 months) for native pasture resources to maintain animals until the next rainy season; and/or (2) increased population density has drastically reduced the area of fallow/common property land which traditionally provided dry-season grazing. One of the most effective and least-cost options open to farmers to increase both stover productivity and quality is the choice of cultivar, provided that there are significant and stable across-environment differences among cultivars for both productivity and quality, and that emphasizing these does not carry an unacceptable penalty in terms of reduction in grain yield. The present work investigates these relationships for 30 cultivars grown for two consecutive years at three contrasting locations in India.

Materials and Methods

Thirty diverse pearl millet cultivars representing the choice of arid-zone landraces, improved open-pollinated varieties and single-cross hybrids available to pearl millet producers in India (Table 1) were grown in three field replications of 6-row plots of 4 m length at three locations (Gwalior, Nagaur and Patancheru) representing the major pearl millet growing zones in India during the rainy seasons of 2000 and 2001. Grain and dry stover yields were recorded approximately one week after grain maturity and a sample of main shoots was separated into leaf blade, leaf sheath and stem internode fractions, dried and ground for stover quality analysis. Stover quality traits nitrogen, *in vitro* digestibility and metabolizable energy content were analyzed using a combination of conventional laboratory analysis with Near Infrared Spectroscopy.

Results and Discussion

The significance of the effects of cultivar, location, year and the interactions of location and year with cultivars on stover nitrogen (N), *in vitro* digestibility (IVD), metabolizable energy content (ME) and yields of grain (GRY) and stover (STY) and yields of digestible (DSTY) and metabolizable (MESTY) stover are presented in Table 2. Except stover N content, cultivar differences were highly significant for all stover quality and grain and stover productivity traits. Location and year had highly significant effects on all stover quality and crop productivity measurements, as expected (Table 2). With one exception, however, cultivar × location/year interactions for all variables were insignificant, suggesting that cultivar differences for both productivity and quality will persist across both years and environments. This conclusion is supported by surprisingly high heritabilities ($h^2 \geq 0.62$) for all variables except stover N content (Table 2).

Stover quality and grain and stover productivity traits of the 30 cultivars across years and locations are reported in Table 1. There were substantial cultivar differences for all stover quality and crop productivity traits except for stover N content. This is consistent with previous findings that stover N content seems to be largely determined by environment (Bidinger and Blümmel 2006). Cultivar-dependent ranges in stover digestibility and metabolizable energy content were about 3.8 and 0.77 units respectively. While these ranges may seem small, they are nutritionally very significant as a difference of 3–4 units in digestibility in grasses resulted in differences in livestock productivity of 17–24% (Vogel and Sleper 1994). Most importantly, there were very substantial cultivar variations in DSTY and MESTY (the products of stover yield and quality, which determine potential animal productivity ha^{-1} of millet stover). Cultivar differences in DSTY ranged from 113 g m^{-2} to 225 g m^{-2}, and in MESTY from 1.6 MJ m^{-2} to 3.2 MJ m^{-2}, representing a range in digestible energy of 1.12 t ha^{-1} and a range in metabolizable energy of 16,000 MJ ha. Such differences will have major implications for on-farm feed resources and livestock productivity.

Table 1. Mean stover nitrogen (N), *in vitro* digestibility (IVD), metabolizable energy content (ME) and yields of grain (GRY) and stover (STY) and yields of digestible (DSTY) and metabolizable (MESTY) stover in 30 cultivars of pearl millet grown in Gwalior, Nagaur, and Patancheru, India, 2000–2001.

Cultivar	N (%)	IVD (%)	ME MJ kg^{-1}	GRY g m^{-2}	STY g m^{-2}	DSTY g m^{-2}	MESTY MJ m^{-2}
BJ 104	0.93	43.3	5.93	168	268	113	1.6
BK 560	0.93	44.7	6.20	163	297	129	1.8
Barmer Population	0.89	44.8	6.40	141	434	193	2.7
CZ-IC 923	0.89	44.3	6.20	205	336	147	2.1
DP Pak Population	0.94	43.6	6.21	153	336	147	2.1
DP Population	0.88	44.1	6.25	172	433	191	2.7
HHB 60	0.82	43.3	6.14	189	347	149	2.1
HHB 67	0.87	42.9	6.06	193	318	135	1.9
HHB 94	0.81	43.1	6.10	190	337	143	2.0
ICMH 356	0.87	44.1	6.14	203	283	122	1.7
ICMH 451	0.90	44.6	6.31	228	393	173	2.4
ICMH 90852	0.89	43.2	6.11	179	279	118	1.7
ICMP 94852	0.89	44.8	6.36	134	366	165	2.3
ICMV 155	0.94	45.3	6.40	203	423	190	2.7
Jakharana Population	0.97	45.6	6.41	161	403	181	2.5
LRE 128	0.85	44.3	6.27	108	357	157	2.2
LRE 179	0.92	45.1	6.28	150	396	177	2.5
Pak LR Population	0.84	42.7	6.09	98	290	124	1.8
Pusa 23	0.91	44.2	6.22	193	299	129	1.8
Pusa 266	0.86	44.8	6.28	167	374	163	2.3
Pusa 322	0.84	43.4	6.10	216	319	137	1.9
RCB-IC 911	0.91	45.5	6.34	220	333	148	2.1
RCB-IC 948	0.89	44.6	6.29	169	318	140	2.0
RCB 2 (99)	0.97	45.4	6.41	151	367	168	2.4
Raj 1	0.88	44.5	6.34	158	450	198	2.8
Raj 171	0.84	44.9	6.35	195	406	181	2.6
Sikar local	0.86	46.5	6.67	129	485	225	3.2
Sulkhania local	0.93	45.9	6.47	139	388	178	2.5
WC-C75	0.91	46.2	6.47	167	434	199	2.8
WRaj Population	0.86	44.4	6.31	149	403	177	2.5
Mean	0.89	44.5	6.27	170	362	160	2.2
Range	0.16	3.8	0.77	130	217	112	1.6

Table 2. Effect of cultivar, location, year and interactions of location and year with cultivars on stover nitrogen (N), *in vitro* digestibility (IVD), metabolizable energy content (ME) and yields of grain (GRY) and stover (STY) and yields of digestible (DSTY) and metabolizable (MESTY) stover in 30 cultivars of pearl millet grown in Gwalior, Nagaur and Patancheru, India, 2000–2001. Data are probabilities of the F statistic for each source of variation.

Source	N	IVD	ME	GRY	STY	DSTY	MESTY
Cultivar	0.57	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Location	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Year	<0.0001	<0.0001	<0.0001	0.01	0.01	<0.0001	<0.0001
Location × cultivar	0.24	0.19	0.06	0.008	0.32	0.34	0.23
Year × cultivar	0.51	0.59	0.16	0.97	0.25	0.30	0.22
Heritability (h^2)	0	0.82	0.81	0.70	0.62	0.67	0.66

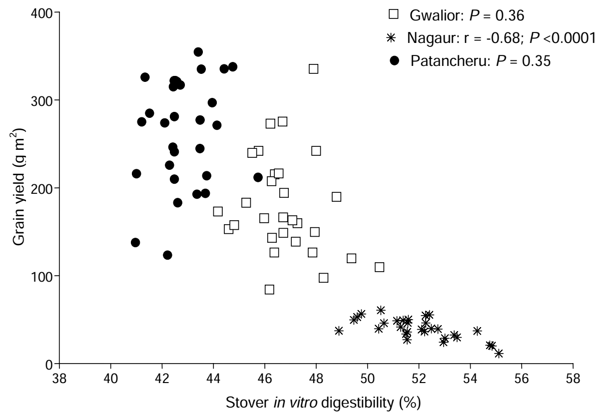

Figure 1a. Relationship between stover *in vitro* digestibility and grain yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2000.

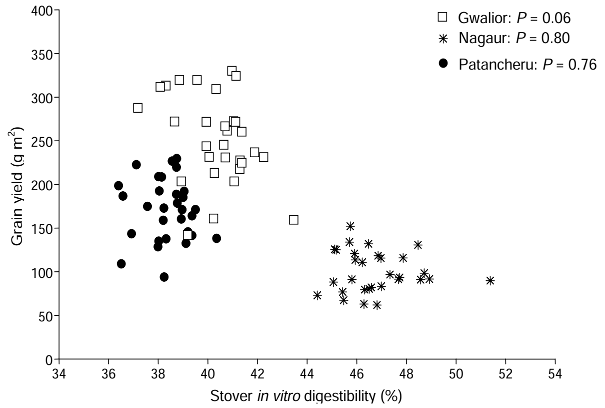

Figure 1b. Relationship between stover *in vitro* digestibility and grain yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2001.

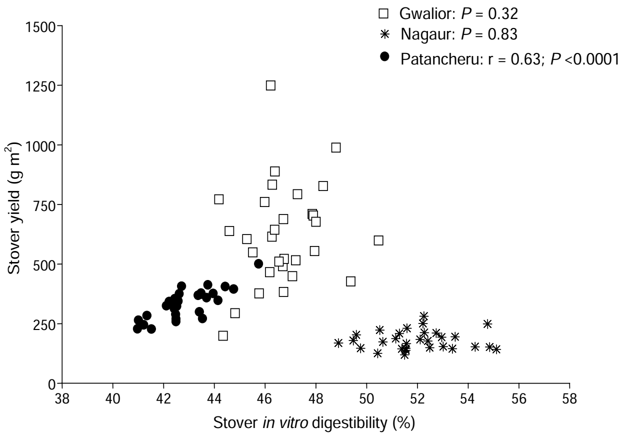

Figure 1c. Relationship between stover *in vitro* digestibility and stover yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2000.

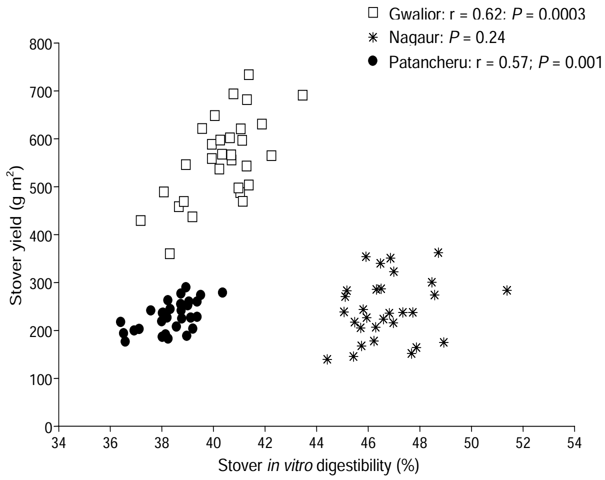

Figure 1d. Relationship between stover *in vitro* digestibility and stover yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2001.

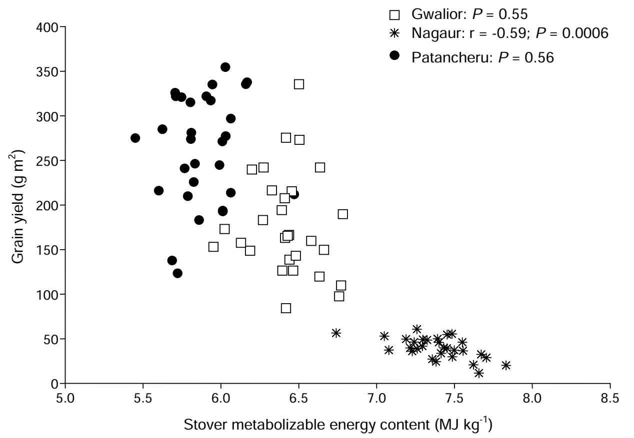

Figure 2a. Relationship between stover metabolizable energy content and grain yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2000.

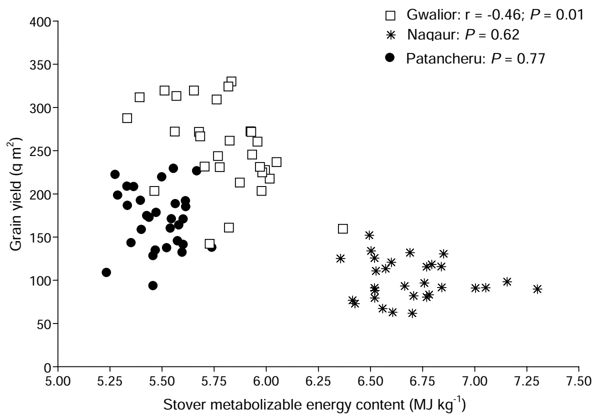

Figure 2b. Relationship between stover metabolizable energy content and grain yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2001.

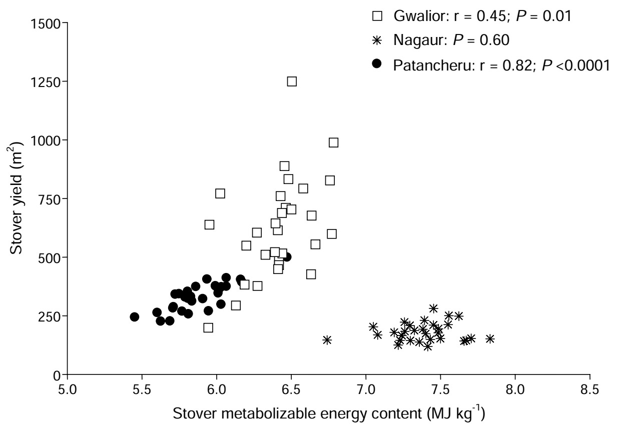

Figure 2c. Relationship between stover metabolizable energy content and stover yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2000.

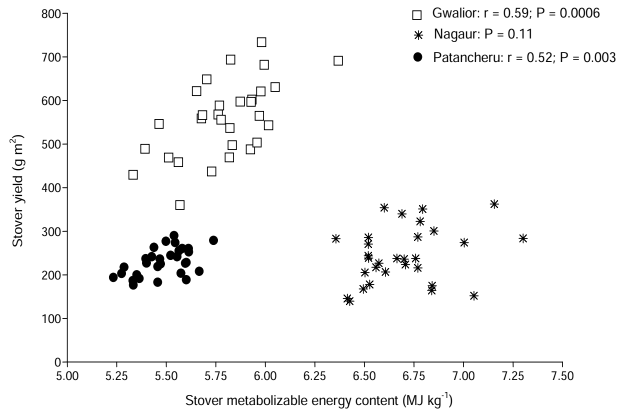

Figure 2d. Relationship between stover metabolizable energy content and stover yield in 30 cultivars of pearl millet grown at Gwalior, Nagaur and Patancheru in India in 2001.

Across years and locations, grain yield was not significantly associated with either DSTY (r = –0.22, P = 0.24) or MESTY (r = –0.24, P = 0.21) suggesting that grain yield and stover yield and quality are compatible traits. Data from individual year and location comparisons support the across-environment and year comparison for the relationships of grain and stover productivity and stover *in vitro* digestibility and metabolizable energy content (Figs. 1; 2). Relationships between grain yield and stover quality traits were largely insignificant, and stover quality and stover yield were frequently positively associated. These results suggest that breeding for improved stover quality is likely to be successful as the major requirements for such programs are fulfilled: stable genetic variability for major quality traits (apart from nitrogen content) and the lack of negative relationships between stover quality and grain and stover yields.

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